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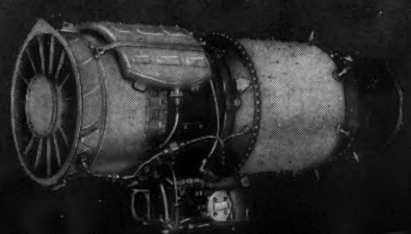
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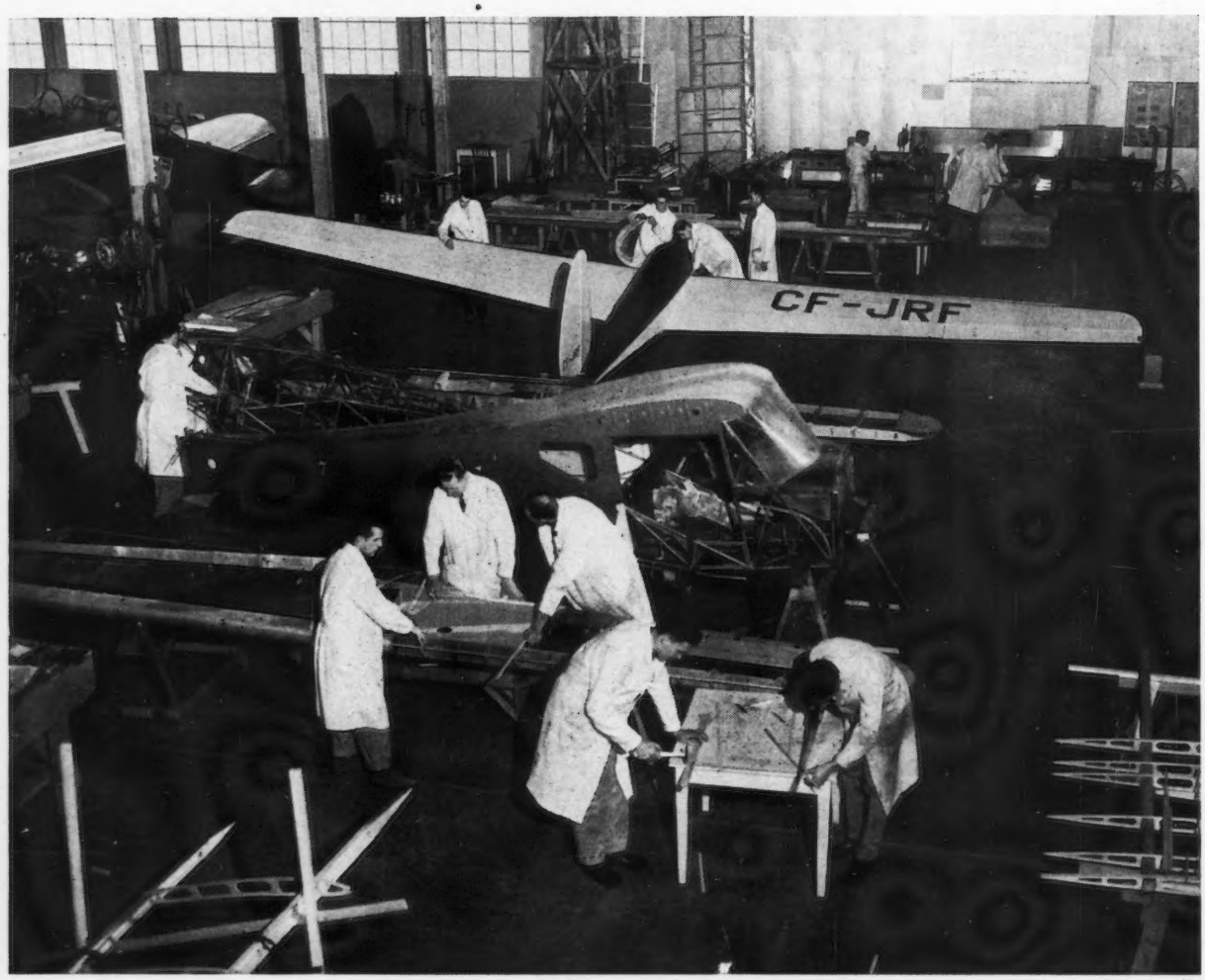
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TECHNOLOGIST TRAINING



A view of the shops of the Department of Aeronautics, Provincial Institute of Technology and Art, Calgary

EDITORIAL

THE CHANGING PATTERN OF ENGINEERING EDUCATION

Prior to World War II, Canadian industry thought in terms of two types of personnel, with university training marking the line of division. At one level we had the production workers, the skilled workers, in fact all those under the rank of foreman or supervisor. Above this we had the engineering personnel consisting principally of graduate engineers.

Due to the fact that the industrial picture in Canada, at that time, was not robust and that we were in the midst of a depression, engineers were used to do many jobs that were not engineering in nature. This practice became so prevalent in Canada that work of this type became the accepted role for the engineer.

In the rapid industrial development years of the post war era, we retained this idea and have been flagrantly guilty of misuse of manpower at the engineering level.

When the bottom of the manpower barrel had been reached in the early '50's and the demand for engineers continued, employers began to look afield for suitable replacements. Through necessity, experience and the influx of technologists from Europe, it became evident that technologists were the answer to the problem. It would be safe to say that in all probability technologists are now used throughout Canada in increasing numbers on jobs that 25 years ago would have been reserved exclusively for engineers.

Since the use of technologists has altered somewhat the manpower picture, it now appears that there is a trend in higher education which may change our present concept of engineering education. Industry now realizes the high potential of the engineering physics graduate. I think employers are somewhat amazed at the versatility of this type of person and realize that the broad background and depth of basic scientific studies make him a most useful employee. This is particularly true now that technologists are becoming available to complete the engineering team.

Could it be that a general pattern of engineering education at the university level may shift towards engineering physics? Many universities now have the first two years common for all types of engineers. How soon may we expect to have all four years of a general nature, with the areas of specialization attained through a few major subjects or at the post graduate level?

In a way, the aircraft industry has become the melting pot for Canadian engineering graduates. Graduates from all Canadian universities are thrown together in one common industry and, within months, it is difficult to tell the alma mater of the graduate or his area of specialization. As far as progress in the industry is concerned, it seems to be dependent upon characteristics of the individual rather than the university or the area of specialization.

Might it be suggested that Canadian universities are, in effect, giving broad and general engineering education, perhaps broader than they realize? If this were not true, we would not enjoy the versatility of the graduates as it now exists.

It would, therefore, appear to be most economical and practical to have a common syllabus for all engineers at the undergraduate level, and leave the sphere of specialization to the graduate schools or the technical institutes.

W. A. B. Saunders,
Vice-Principal,
Provincial Institute of Technology and Art

AIRCRAFT AND SPACECRAFT PROPULSION†

by A. M. Rothrock*

National Aeronautics and Space Administration

SUMMARY

In the fifty years since the first powered flight in Canada the propulsion system has become increasingly important in determining the speed, distance and altitudes at which we can fly. For the first forty years of flight the reciprocating engine, driving a propeller, dominated the field. As the velocity approached that of sound and altitudes exceeded 30,000 ft, the thrust weight ratio of the reciprocating powerplant became excessive and a new means of propulsion was required. The turbine engine – either turboprop or turbojet – met these requirements. At flight speeds up to 0.8 the speed of sound, the efficiency of the turboprop has led to its adoption. For higher speeds to $M = 3.0$ the turbojet engine, with or without afterburner, is predominant. Above $M = 3.0$ and within the earth's atmosphere, the picture is not so clear. There is uncertainty concerning the speeds and altitudes of interest and in whether the propulsion system will be a ramjet or a combination turbojet and ramjet.

For flight outside the earth's atmosphere, the chemical thermal rocket currently dominates the picture and will do so until the research on nuclear devices leads to practical engineering applications. The choice between liquid or solid chemical propellants for space propulsion is currently being decided in favour of the former, except for smaller upper stages. Additional research is needed to determine the full potential of either system.

As progress is made in adapting nuclear energy to spacecraft, the currently too difficult space missions will become more practical. The choice between nuclear-thermal and nuclear-electric systems is uncertain at this time. Again, research is required.

The research emphasis in flight propulsion has, in the last few years, swung from air-breathing to rocket engines. This trend has increased the required research areas many times. There is a great need for the kind of exploratory research that will permit us to focus our efforts. The expense and time involved makes coordination and organization of effort increasingly important.

INTRODUCTION

THE propulsion system of an aircraft or a spacecraft is a device for accelerating a gas (the propellant) rearward from the craft, and so producing a force to propel the craft. With an aircraft the gas is, in general, either the air through which the craft is flying or the combustion products formed by burning the air. In a spacecraft the gas is formed from products carried aboard the craft. In either an aircraft or spacecraft the energy source for accelerating the propellant can be chemical or nuclear. In an aircraft the acceleration is produced either directly or indirectly by thermal expansion of a gas. In a spacecraft, either thermal expansion or an electric process can be used to produce the acceleration. Furthermore, looking to the future, the propulsive force on a spacecraft may be produced by accelerating energy rather than mass from the vehicle. In an aircraft the propulsion system is required to operate continuously for a matter of hours. In a spacecraft the propulsion system may operate from a few seconds to a few minutes to many days.

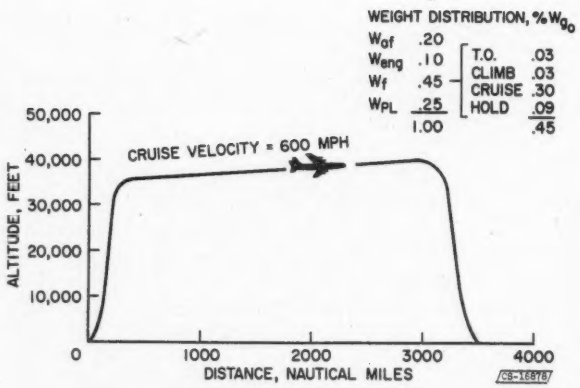


Figure 1
Representative transport aircraft flight plan and weight distribution

As representative of the missions to be performed by aircraft and by spacecraft, Figures 1 and 2 are presented. Figure 3 summarizes the numerical values of the velocity changes shown in Figure 2. With the airplane, the accent is on range at a desired velocity and altitude. With a spacecraft, the accent is on change in velocity. The basic equations involved are:
For the aircraft:

$$R_v = E_{sp} \frac{L}{D} \ln \frac{M_G}{M_G - M_F} \tag{1}$$

For the spacecraft:

$$\Delta V_v = g\, I_{sp} \ln \frac{M_G}{M_G - M_P} \tag{2}$$

in which

R_v aircraft range
ΔV_v change in spacecraft velocity

†Paper read at the Special Anniversary Meeting of the C.A.I. in Montreal on the 24th February, 1959.
*Assistant Director of Research.

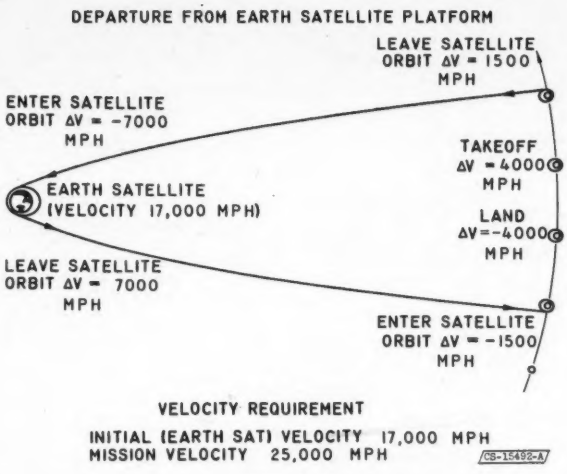


Figure 2
Moon landing

(1) To reach earth orbit	+ 17,000 MPH
(2) To leave earth orbit	+ 7,000 MPH
(3) To enter moon orbit	− 1,500 MPH
(4) To land on moon	− 4,000 MPH
(5) To reenter moon orbit	+ 4,000 MPH
(6) To leave moon orbit	+ 1,500 MPH
(7) To enter earth orbit	− 7,000 MPH
(8) To land on earth	− 17,000 MPH
Total Velocity Change	59,000 MPH

Figure 3

E_{sp}	specific energy of airplane propellant system; i.e. foot pounds of work (thrust times distance) per pound of fuel consumed
I_{sp}	specific impulse of space vehicle propellant system, i.e. pounds of thrust produced per pound of propellant discharged per second
$\frac{L}{D}$	lift drag ratio of airplane, i.e. reciprocal of pounds of thrust required per pound of airplane
g	gravitational acceleration
M_G	gross mass of aircraft or spacecraft at start of flight
M_F	mass of fuel consumed during airplane flight
M_P	mass of propellant consumed during spacecraft velocity change

The value of E_{sp} is the product (in correct units) of the heat of reaction of the fuel times the overall efficiency of the powerplant. With a non-afterburning turbojet engine this efficiency varies from about 0.20 at 0.9 the speed of sound ($M = 0.9$, i.e. 600 mph) to 0.40 at $M = 3.0$. The heat of combustion of the fuel is, essentially, a constant.

Assuming a turbojet engine with these efficiencies and using a conventional hydrocarbon (petroleum) fuel, one pound of jet fuel will produce one pound of thrust for approximately 500 miles at an airplane velocity of $M = 0.9$. At a speed of $M = 3.0$, the value will be about 1,000 miles. With a boron fuel a further increase of 20 to 40% might be obtained.

With a nuclear powered aircraft the heat of combustion is of the order of a million times that of chemical fuels, and Eq. (1) has little significance. Suffice it to say that if a nuclear powered plane will fly at all, it will fly very far.

The specific impulse, I_{sp}, of the spacecraft propellant is a function of the square root of the energy transferred to each pound of propellant, chemical or nuclear, thermal or electric, and the efficiency with which this energy is effective in accelerating the propellant. This efficiency is independent of the velocity at which the spacecraft is travelling. For thermal systems it varies between 0.65 to better than 0.80, depending on the pressure ratio across the discharge nozzle.

The specific impulse for a chemical thermal process (chemical rocket) varies between 200 to 400 pounds of thrust per pound of propellant discharged per second. For a nuclear thermal process (nuclear rocket) the values are 800-1,200 pounds of thrust per pound of propellant discharged per second. The propellant velocity relative to the vehicle may be substituted for $g\ I_{sp}$ in Eq. (2), that is the propellant velocity in feet per second is 32.2 times the specific impulse in pounds of thrust per pound of propellant discharged per second. Under those circumstances in which there is an appreciable gravitational force acting on the spacecraft, such as launching from the earth, Eq. (2), using V_P, is rewritten as:

$$\Delta V_v = V_P \ln \frac{M_G}{M_G - M_P} - g_e t \qquad (3)$$

in which

V_P	propellant discharge velocity relative to vehicle
g_e	effective gravitational force due to proximity of vehicle to other bodies
t	time of propellant discharge, i.e. of vehicle acceleration

The lift/drag ratio for current subsonic transport airplanes can be of the order of 20:1. At speeds of $M = 3.0$ the situation is less certain but values of a third those at the subsonic speeds are considered in design studies.

In the mass ratio there is considerable difference between the airplane and the space vehicle. Figure 1 lists representative weight distribution for a long range commercial jet transport. Considering reasonable variations from this figure, $\frac{M_G}{M_G - M_F}$ might vary from 1.5 to 2 and the logarithm from 0.4 to 0.7 with a corresponding subsonic range of 4,000 to 7,000 miles for payloads varying respectively from 25 to 15% of the gross takeoff weight. With the space vehicle the effective value of the mass ratio can show considerably more variation. Since the distances flown are orders of magnitude greater than those considered for aircraft and since space flight is still in the research and development stage, the ratio of payload to gross weight or mass does not have the same economic considerations as for the airplane. In addition, it is practical to stage rockets, whereas staging of airplanes is of quite limited value. For a staged vehicle, the velocity increase for each successive stage, Eq. (2), is

added to the velocity increase of the previous stage or stages and the equation can be rewritten in the form

$$V_v = g\, I_{sp} \left(\ln \frac{M_{G1}}{M_{G1} - M_{P1}} + \ln \frac{M_{G2}}{M_{G2} - M_{P2}} + \ln \frac{M_{G3}}{M_{G3} - M_{P3}} \right) \quad (4)$$

in which $(M_G - M_P)$ represents the mass of the powerplant and structure for the stage under consideration plus the sum of the masses of all successive stages and the final payload. With a mass ratio of three per stage and seven stages the sum of the logarithms becomes 7.7. Assuming a representative value of I_{sp}, the velocity increase per stage will be of the order of 7,000 mph. The total velocity change for seven stages becomes then 54,000 mph, which, allowing for gravity losses, is about the velocity increment (42,000 mph) required to leave the earth, land on the moon, and then return to an earth orbit.

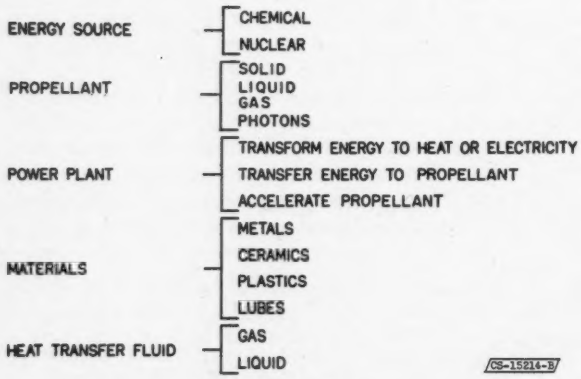


Figure 4

Propulsion system components for aircraft or spacecraft

The propulsion system for the airplane or space vehicle can be considered, Figure 4, to consist of: (1) an energy source; (2) the mass to be accelerated from the vehicle; (3) the powerplant, the purpose of which is to transfer the energy from the chemical or nuclear form in which it is carried in the craft into heat or electricity and to transfer the energy to the propellant in a manner that causes the propellant to be accelerated from the vehicle, so producing the propulsive force. Also listed in the figure are the materials of which the powerplant is made and a heat transfer fluid. The heat transfer fluid may or may not be required.

The propellant for the airplane is the air through which the airplane is flying or the exhaust gas formed by burning this air. Considering the latter case, the velocity increase to which the propellant is accelerated within the engine is the difference between the exhaust gas velocity relative to the airplane and the velocity at which the airplane is flying. For the spacecraft, since an atmosphere is not available, the propellant is carried aboard in any convenient form, generally as a solid or liquid. It is converted into a gas within the powerplant for convenience in the acceleration and discharge process.

With this general discussion, we will examine in more detail certain of the propulsion systems currently used or considered, placing most of our emphasis on systems for spacecraft.

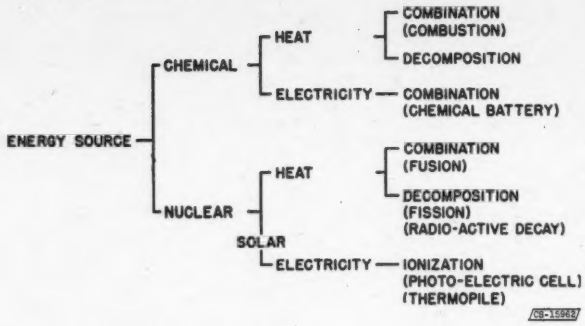


Figure 5

ENERGY SOURCES

As shown, the energy used to accelerate the propellant is either nuclear or chemical, Figure 5. In either case, combination or decomposition of chemical elements or compounds is involved, and heat or electricity can be produced. With aircraft (exclusive of rocket boost) only chemical combination to produce heat is currently used, although much time and effort is being expended towards the development of a satisfactory nuclear reactor as a heat source. For space propulsion, all phases listed on the figure are under consideration, although current usage is limited to chemical combination or decomposition for the production of heat. In considering the energy sources, it is desirable to examine the energies released by nuclear or chemical reactions. Figure 6 shows the estimated energy released by fusion of hydrogen through calcium, or fission of uranium through bromine, as a function of atomic mass number. These estimates are for the fusion to the order of calcium or fission to the order of bromine. The curve is drawn to show the general trend and not to give specific values. In practice, the energy released through fission of the heavy elements of interest is, as shown, about 50×10^9 BTU per pound. In the case of fusion, hydrogen has been fused to helium, rather than to elements of about 40 atomic mass. In this case, the energy release is also about 50×10^9 BTU per pound. The same considerations apply to the choice of nuclear energy for either aircraft or spacecraft.

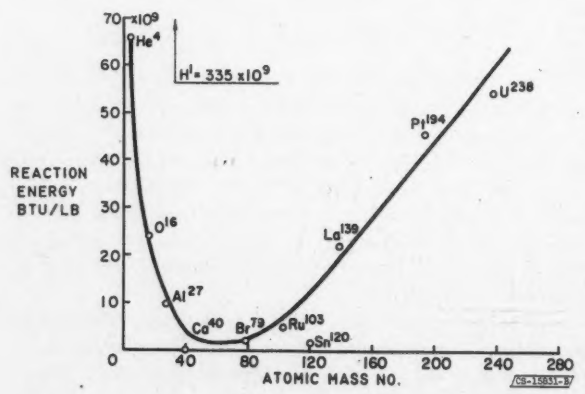


Figure 6

Maximum nuclear energy available from fission or fusion reactions

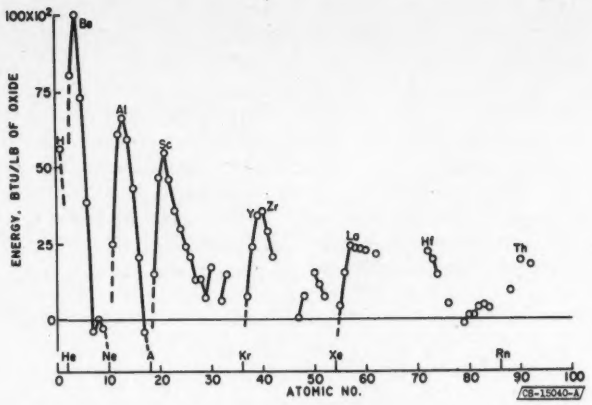


Figure 7
Reaction energy with oxygen

A first approximation of the elements of interest as chemical fuels for the production of either heat or electricity is shown in Figure 7, in which the reaction energy, with oxygen, is plotted against atomic number for the various elements. The curve shows the periodic variation expected in such a plot. As a first approximation, the elements are hydrogen and those close to the maxima occurring with beryllium, aluminum and scandium. The decrease in the maxima, with increase in atomic number, results from the increased molecular weight of the oxide.

The chemical fuel of most interest for aircraft is petroleum. However, other chemicals have been, or are being, considered for special purposes. Since, with the airplane, only the fuel is carried aboard, the criteria of interest is the heat energy per pound of fuel (rather than per pound of combustion products) and the combustion temperature. Figure 8 shows the values for the lighter elements in the periodic table. Hydrogen has several times the value of any of the other elements listed. Its low density in the liquid form and the relative difficulty of handling it has discouraged its use as an airplane fuel. Considering beryllium, lithium, and boron, research and development is being conducted on boron compounded with carbon and hydrogen. The high melting temperature of boron oxide relative to the permissible tempera-

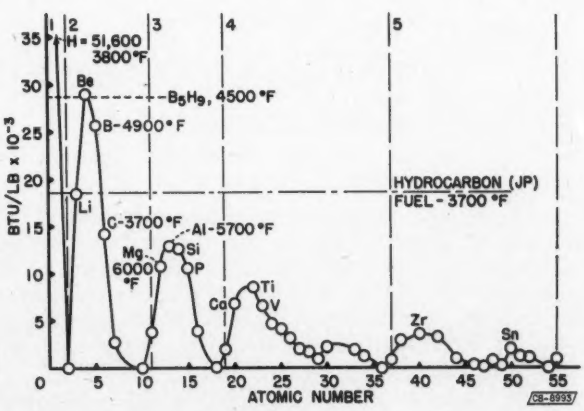


Figure 8
Heat of combustion of elements

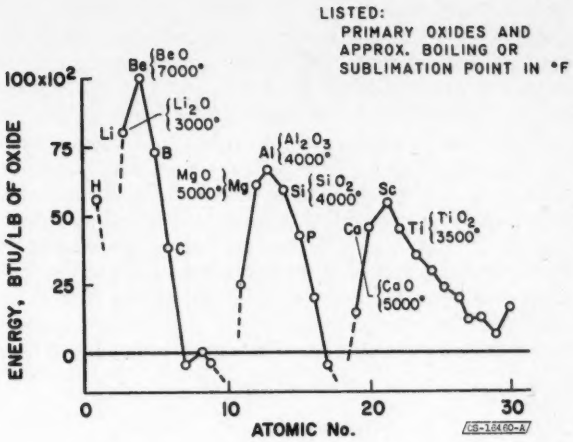


Figure 9
Reaction energy with oxygen

tures in the turbojet engine presents many difficulties. Also, the cost of such a fuel will probably prevent its commercial use except in special cases. Magnesium and aluminum have received attention as a means of increasing the combustion temperature and, thereby, the thrust per pound of air. However, the use of rocket assist seems to be a simpler means of augmenting airplane thrust.

Turning to the chemical rocket, a first approximation of the chemicals of interest as fuels is shown in Figure 9, in which the data from Figure 7 are again shown for the first 30 elements. Since both fuel and oxidant have to be carried in the rocket propulsion system, the energy is expressed in BTU per pound of the oxide formed. For several of the elements, the primary oxides are shown and the approximate boiling temperatures of the oxides. For boiling temperatures of 3,000°F or more, difficulties can be assumed as a result of exhaust gas condensation. For this reason, the elements so listed are considered in sufficiently limited quantities so that the oxides formed are a small proportion of the exhaust gas.

The chemicals of interest as fuels and oxidants for aircraft and spacecraft are summarized in Figure 10.

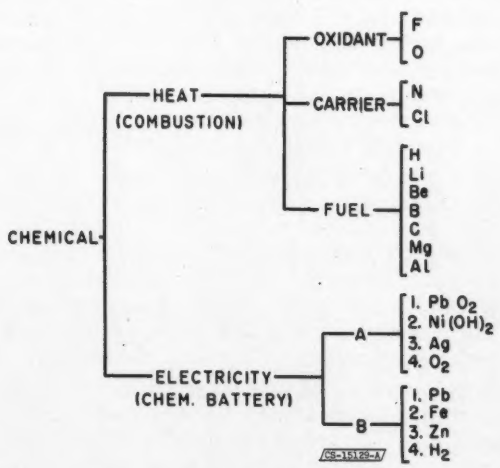


Figure 10

The oxidants are oxygen or fluorine. In addition, two carriers are included, nitrogen and chlorine. They are used because of their low atomic weight in relation to other carriers that might be considered. For the airplane engine, the oxidant is, of course, the oxygen in the air.

Since the production of electricity by chemical batteries is of interest in spacecraft, the more common compounds used in the generation of electricity are included in Figure 10. The numbers give corresponding "oxidants" and "fuels", that is the corresponding elements of the chemical battery, generally termed "half-cells". Because heavier elements are involved in the first three combinations, they yield a low ratio of energy released to weight consumed. For this reason, the hydrogen-oxygen cell is of particular interest in spacecraft operation.

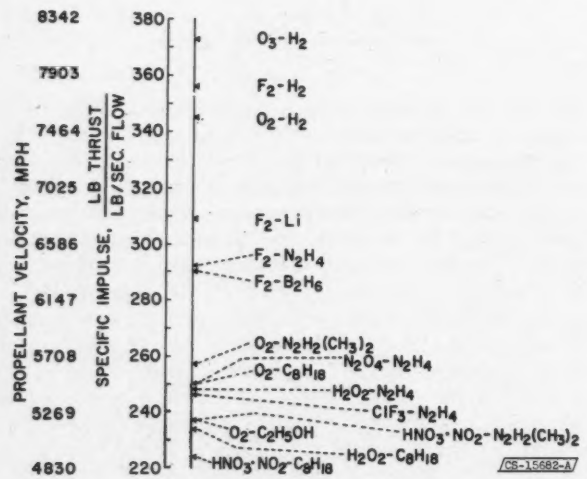


Figure 11
Performance of representative rocket propellants
P_c = 300 frozen expansion P_e = 14.7

PROPELLANTS

Considering the chemical rockets, representative chemical fuels and oxidants (which form the propellant) are listed in Figure 11. Solid propellants are not included, because security classification is more limiting here than is the case with liquids. The continued occurrence of oxygen, hydrogen, and nitrogen is noted. The ordinate, that is the energy criterion, is listed as specific impulse and as propellant velocity.

As a generality, as the specific impulse of the propellants increases, the oxidant and fuels forming the propellants tend to go, at ordinary temperatures and pressures, from solid, to liquid, to gas. This fact has led to the extensive use of a cryogenic (liquified oxygen) as an oxidant, and to the interest in another cryogenic (liquified hydrogen) as a fuel. The use of cryogenics presents many problems in handling and storing.

In general, the research objective in chemical fuels and oxidants, either liquid or solid, is to increase the percentage of the lighter elements in the fuel and the percentage of oxygen or fluorine in the oxidant. Research is being conducted on the possible use of free radicals for fuels or oxidants, but the work to date does not indicate successful solutions to the problems involved.

Rockets, such as those discussed, in which the propellant is heated to a relative high temperature by either nuclear or chemical energy can be termed thermal rockets. In this case, the increase in the random molecular velocity resulting from the heating is partially changed into directed velocity by expanding the gas through the rocket nozzle. The propellant velocity can, therefore, be indicated by the expression

$$V_P \sim \sqrt{\frac{T}{m}} \qquad (5)$$

in which

T the temperature to which the propellant is heated

m average molecular weight of propellant

For chemical-thermal rockets, the temperature and the average molecular weight are dependent on the oxidant and fuel used and the pressure and the oxidant/fuel ratio. This mixture ratio is adjusted to that giving a maximum value of $\sqrt{\frac{T}{m}}$.

In the nuclear-thermal rocket the permissible temperature is that permitted by the reactor. The molecular weight can be 2, or somewhat lower, due to dissociation, if hydrogen is the propellant gas. This lower molecular weight results in specific impulses of the order of 1,000 pounds per pound per second (propellant velocity 22,000 miles per hour) with a corresponding decrease in mass of propellant required. The limit on specific impulse is the temperature limitation of the reactor. This limitation could be raised if the nuclear reaction could take place within the propellant gas.

A method of removing or lessening the temperature limitation is to use electrical, rather than heat, energy to accelerate the propellant. In this case, the propellant particles are charged electrically and then subjected to an electric or electromagnetic field. The force on the particles produced by the field accelerates the particles and, therefore, the propellant, in a directed manner. In this case, the relationship is

$$V_P \sim \sqrt{\frac{QE}{m}} \qquad (6)$$

in which

Q charge on particle, generally that on one electron

E the voltage applied across the field

m particle mass, molecular weight if particle is a molecule

The applied voltage for electrical acceleration is not limited as is the temperature in thermal acceleration. Consequently, not only can molecules or particles of relatively high weight be used, but propellant velocities of several hundred thousand miles an hour can presumably be attained. It is almost certain that the energy source in this case will be nuclear.

For the above propulsion system, the energy required to charge the particles is of interest. This energy is not available for the acceleration process. Figure 12 shows

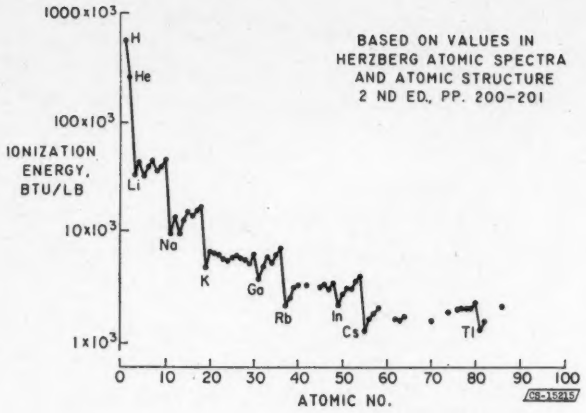


Figure 12
Ionization energies of the elements in BTU per lb (first electron)

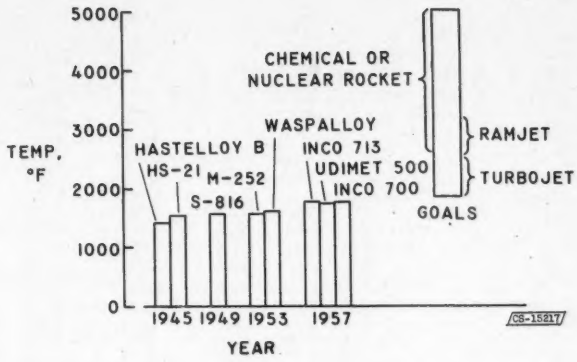


Figure 14
Operating temperature of materials

the ionization energy for the conditions specified plotted as a function of atomic number. Again, the periodic nature of the variation is evident. The ionization energy to ionize atomic hydrogen is of the order of 100 × the energy available from the combustion of an equal weight of hydrogen and oxygen to H_2O. The data indicate that for the electric, or electromagnetic systems, the heavier elements are of interest. Cesium, because it is a liquid at normal temperatures and pressures, is of particular interest.

If the propellant is an ionized gas, the electrons removed in the ionization process are physically removed from the ions and both ions and electrons are accelerated and discharged by means of an electric field. If the conditions under which the ions are formed are such that the ions and electrons can remain together without recombining, the mixture is termed a plasma and the accelerating force is produced by an electromagnetic field.

The propellants for use in either thermal or electric acceleration are summarized in Figure 13, according to the accelerative process. An additional process, "radiated", has been introduced to indicate the use of energy (photons) discharge, or reflection, rather than mass discharge to produce the propulsive force.

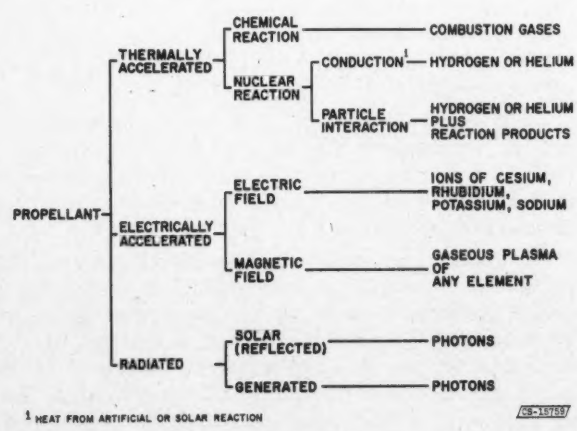


Figure 13

MATERIALS

Turning to the materials of use in either spacecraft or aircraft propulsion systems, a major requirement is the ability to withstand the high temperatures involved. Figure 14 shows the current temperature limitations for turbojet engine turbine blade materials and also the desired temperature range. Progress made over the last several years has permitted the turbine inlet temperatures to be raised about 300°F. As an indication of materials of interest to achieve higher temperatures, the melting temperatures of the elements plotted against atomic number are presented in Figure 15. For the metals, the first maximum includes the metals currently used as the bulk of the high temperature alloys, vanadium, chromium, cobalt, and nickel. The successive maxima include, respectively, zirconium, columbium, molybdenum, tantalum and tungsten. These materials present difficulties in use both from the standpoint of processing and from reaction with oxygen or other fluids with which they might come in contact. Ceramics or cermets present possibilities providing resistance to thermal shock can be

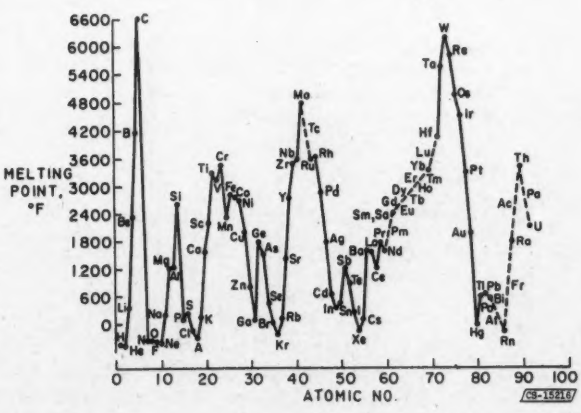


Figure 15
Melting temperatures of the elements vs atomic number

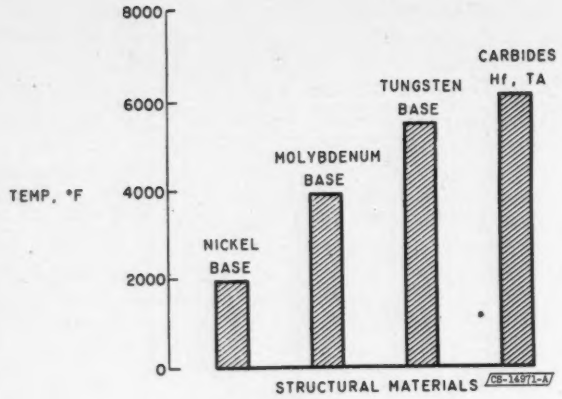


Figure 16
Estimated operating temperatures for materials

improved. Figure 16 shows material temperatures that might be achieved if 80% of the melting temperatures of some of the materials of interest could be withstood. Current alloys are use at temperatures of 60 to 80% of the melting temperatures, depending on the stresses involved. Based on past rates of progress, rapid improvement in the field of materials cannot be counted on.

HEAT TRANSFER FLUIDS

Heat transfer fluids should have high specific heat (that is low molecular weight), high density, low corrosivity, a melting temperature that is acceptable and low radioactivity. These properties are not mutually compatible. Figure 17 summarizes the fluids of most interest.

THE POWERPLANT

Having examined the energy source, the propellant, the high temperature materials, and the heat transfer fluids, the complete powerplant will now be considered. As stated previously, there are three major functions to be performed: (1) convert the chemical or nuclear energy into heat or electricity; (2) transfer the energy to the propellant; and (3) accelerate and discharge the

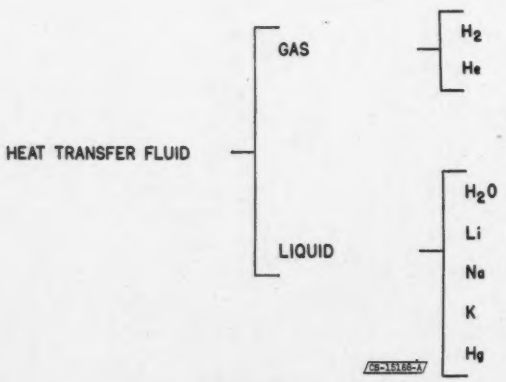


Figure 17

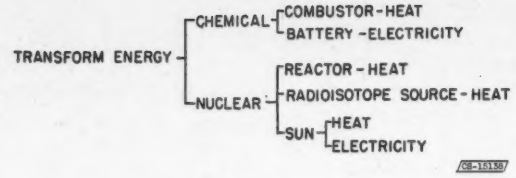


Figure 18

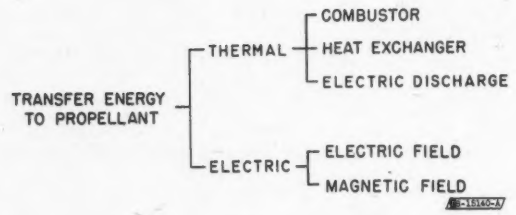


Figure 19

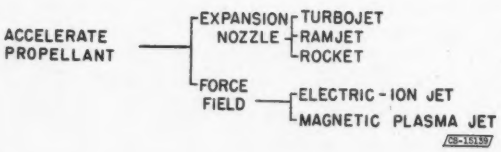


Figure 20

propellant. The energy conversion is considered in Figure 18. For either the airplane or rocket engine the chemical energy is normally transferred into heat in the combustion chamber. A chemical battery is included in the figure, since its use is of interest in spacecraft power generation. For nuclear energy, a reactor is considered to be the aircraft applications for either a turboprop, turbojet, or ramjet. With a spacecraft use of a radioactive isotope can be considered as a heat energy source and studies and experiments are being conducted on such use. Energy from the sun is a subject of study for spacecraft propulsion or power generation, but much research is required to determine the practicality of such a propulsion system.

The energy is transferred to the propellant by the devices designated in Figure 19. An electric discharge is listed as a means of heating the propellant, although the applicability of such a device in relation to the others listed is not too clear.

If a thermal process is used, the acceleration of the propellant, Figure 20, is accomplished in an expansion nozzle. In this case, the increase in the random molecular velocity resulting from the heating is changed by the expansion process into a directed velocity and consequent acceleration of the propellant mass. With an ion or plasma jet, a field either electric or electromagnetic provides the accelerating force for the propellant mass.

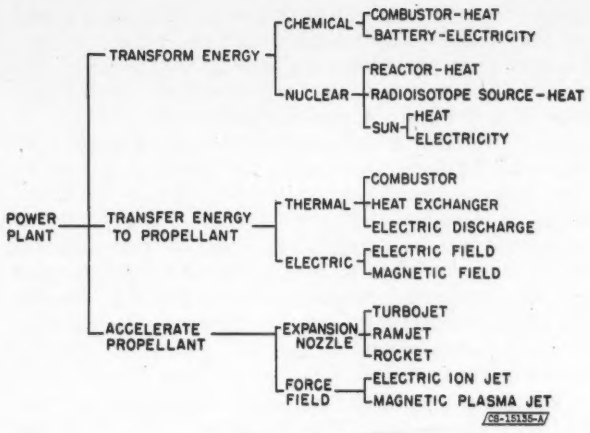


Figure 21

Vehicle	F/W
Aircraft	0.05– 1.2
Ballistic Missile	1.2 – 6.0
Spacecraft	1.2 –10^{-5}

Figure 22
Ratio of thrust required to vehicle weight

Combining these three figures, the powerplant is summarized in Figure 21.

The types of powerplants involved and their suitability for different missions will now be examined. Figure 22 lists the ratio of suitable thrust to vehicle gross mass (or weight in connection with operation close to the earth's surface). For the aircraft, the range is from 0.05 (lift/drag ratio = 20) to say 1.2 for a vertical takeoff airplane. For a ballistic missile or spacecraft earth launching system (booster system) a thrust in excess of the gross weight is required. As propellant is discharged, thrust/weight ratio, of course, increases. In practice, the ratio for the missile varies about as shown. When a spacecraft is at a sufficient distance from the earth or other solar body so that gravitational forces can be neglected, or when the craft in orbit has sufficient centrifugal force to balance the gravitational forces involved, propulsive forces of a quite small fraction of the vehicle mass can be considered. Ratios from an earth launch to flight in deep space are listed as 1.2 to 10^{-5}.

Another factor which must now be considered is the power in the propellant jet.

$$P_P = \frac{1}{2}\frac{M_P}{t} V_P^2 \qquad (7)$$

in which

P_P is power in jet.

The force, or thrust, produced by the jet is

$$F = \frac{M_P}{t} V_P \qquad (8)$$

in which

F is thrust produced

	H. P. PER LB THRUST	LB ENG. PER LB THRUST	I_{sp}, LB THRUST/ LB PROP. PER SEC
TURBOJET	2	0.30	60[1]
CHEMICAL ROCKET	12	0.015	360
NUCLEAR ROCKET	28	0.045	840
ELEC.-MAG. ROCKET	330	1,000 TO 5,000	10,000

[1] 3,600 LB/LB FUEL/SEC^{-1}

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Figure 23
Comparison of aircraft and spacecraft propulsion systems

Obviously, this force can be kept constant by decreasing the mass rate of propellant discharge $\frac{M_P}{t}$ and increasing V_P proportionately. However, in this case, the jet power is increased to the same degree the velocity is increased.

With any of the chemical-thermal powerplants the weight entailed in the power generation is relatively low. However, in an aircraft nuclear powerplant in which shielding is required, or in an electrical propulsion system, this is not the case. Figure 23 lists the horsepower per pound of thrust for the various powerplants other than the aircraft nuclear system. The turbojet is assumed to be without afterburner. The nuclear rocket weight is considered to include minor shielding. For the nuclear powered aircraft (not included in Figure 23), it is assumed that takeoff and landing are with chemical fuel. The nuclear portion of the powerplant can, therefore, weigh 30% of the gross weight (cruise fuel weight as shown in Figure 1). Assuming a lift/drag ratio of 16, the permissible installed nuclear weight at the flight conditions is 4.8 lb/lb thrust or 2.4 lb/jet hp produced. Assuming an engine thermal efficiency of 30%, the permissible weight is 0.72 lb/hp delivered from the reactor of 0.5 lb/KW. These figures are to be considered as only approximations.

The electrical or electromagnetic rocket powerplant weights are measured in thousands of pounds per pound of thrust. For this reason, they are considered for those conditions of space flight in which thrust/mass ratios of the order of 10^{-4} are permissible.

Air breathing engines

Coming to the engines, the turboprop engine and the turbojet engine are reasonably well developed. For the turboprop and for the turbojet engine to $M = 2.0$, most of the required research has been completed. There will be, of course, normal engineering product improvement. An unresolved problem is the future of turbine cooling. Much research has been done on internal air cooling of the blades, but its use has not been incorporated in production engines. If it can be successfully applied to turboprop engines, there will be a marked decrease in specific engine weight. Manufacturing difficulties have so far proved overriding.

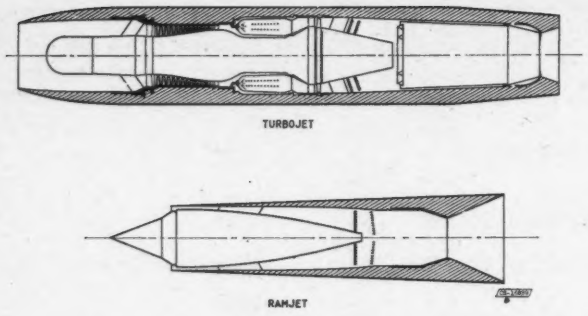


Figure 24
Representative turbojet and ramjet engines

The research on turbojet engines, Figure 24, has led to shorter combustion chambers, higher altitude limits, increased airflow rates per unit engine frontal area, increased turbine and compressor efficiencies, improved compressor stall characteristics, variable engine inlets and exhausts. For airplane speeds above $M = 2.0$, and particularly above $M = 3.0$, additional research is required on inlets and exhausts and on the temperature problems that will result from the higher flight speeds.

The ramjet, Figure 24, has an uncertain position in the propulsion system spectrum. Its apparent simplicity is misleading. Through research, it has been made an efficient engine, but as its development progressed the upper Mach limit considered for the turbojet has increased. The future of the ramjet is partially dependent on the maximum flight speeds at which airplanes will be used. Consideration has been given to combining the turbojet and ramjet in the so-called dual cycle engine.

Rocket engines

In the field of rocketry, both thermal and electric, there is a great deal of research to be done. Figure 25 shows chemical solid and liquid propellant rockets and the nuclear thermal rocket. These rockets are listed as temperature limited inasmuch as the temperature of the propellant is limited either by material temperatures already discussed or by combustion temperatures. These rockets are examined in relation to the permissible values of T and m (Eq. (5)) in Figure 26. The values listed are approximate. Reasonable changes in them will not affect this discussion. In the solid propellant rocket, burning takes place from the center to the outside. Consequently, the propellant case (which is the combustor) is not subject to too severe temperature limitations. The nozzle must, however, withstand the total combustion chamber temperature for the full duration of operation. Since the nozzle generally is not cooled and since the combustion chamber temperatures are of the order of 5,000°F, the duration of operation is definitely limited. The molecular weight of the propellant is limited by the requirement that oxidant and fuel be intimately intermixed in the solid form with properties permitting burning at a predetermined rate. These requirements currently lead to higher molecular weights for the propellant gas than is the case with the liquid chemical rocket. With the liquid chemical rocket, the combustion chamber, as well as the nozzle, is subject to the full combustion temperature for the duration of operation, but since either the liquid fuel or oxidant may be circulated in suitable coolant passages along the nozzle and combustion chamber, the duration of operation can be considerably longer than that with the solid propellant rocket. In addition, by going to liquids (including gas that must be liquified by means of refrigeration), lower molecular weight combustion gases can be obtained with the consequent increase in exhaust (that is propellant) velocity. By so proportioning the propellants that hydrogen exists in appreciable quantities in the exhaust, a maximum value of T/m is obtained at values of T lower than that for the stoichiometric ratio. The liquid propellant rocket requires the complication of fuel and oxidant tankage and pumping systems.

By using a nuclear reactor for the source of heat, hydrogen can be used as the propellant with a molecular weight of 2 or less (depending on dissociation) with the consequent increase in the ratio T/m. However, in this case, the heat flow is from the solid material of the reactor fuel elements (considering a conventional reactor) to the fluid propellant. Therefore, the propellant temperature must be lower than the permissible material temperature. Two material temperatures are shown without consideration of how these material temperatures might be achieved. The last column shows the

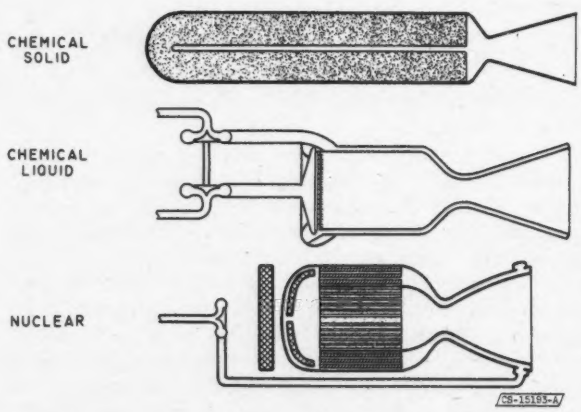


Figure 25
Temperature limited thermal rocket engines

PROPELLANT	TEMPERATURES, °F		EFFECTIVE MOL. WT.	JET VELOCITY, MPH
	PROPELLANT	MATERIAL		
		CHEMICAL		
SOLID	5500	600 [1] – 3500 [2]	30	5000
RP-1 – O_2	5500	1200	22	6000
H_2 – F_2	5000 – 7000	1400	11	8500
		NUCLEAR		
H_2	3250	3500	2	14,500
	5250	5500		18,500

[1] CASE
[2] NOZZLE

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Figure 26
Comparison of temperature limited thermal rockets

extent to which the propellant velocity, that is specific impulse, is increased by perfecting the changes indicated.

Chemical rocket staging

The manner in which chemical-thermal rockets meet the requirements of a booster system for spacecraft is shown in Figures 27 and 28.

In the data presented, a propellant velocity of 6,000 mph (specific impulse = 273 lb per lb per second) is assumed. This value is representative of that for the $O_2 - C_8H_{18}$ combination under conditions of a higher pressure ratio than that assumed for the data in Figure 11. Using certain assumptions which will not be discussed here, the vehicle velocity increase is shown as a function of the ratio of mass of propellant discharged, M_P to gross vehicle mass, M_G at launching. In the equations shown on the figure, M_{St} is the weight of the rocket stage less propellant. On the curve are listed the necessary velocities to achieve various missions shown, assuming the vehicle is launched from the earth. The intermediate range (1,500 nautical miles) missile (IRBM) requires a velocity increase of 9,500 mph at burnout; the intercontinental ballistic missile (ICBM) (range = 5,500 nautical miles) a velocity of 16,000 mph; the earth satellite a velocity of 17,000 mph; and the moon probe, 24,000 mph. All values are approximate. For the moon probe, the velocity is that required to leave the earth's surface and approach sufficiently close to the moon so that the moon's gravitational pull on the vehicle exceeds that of the earth. The gross weight of the vehicle at takeoff is:

$$\frac{M_P}{M_G} = \frac{M_P}{M_{St} + M_P + M_{PL}}$$

in which

M_{St} is mass of rocket stage, less propellant, less payload, i.e. the mass of the stage structure, including the powerplant.

M_{PL} is mass of the payload. In a multistage rocket the payload of each stage is the sum of the masses of all succeeding payloads, plus that of the payload of the final stage.

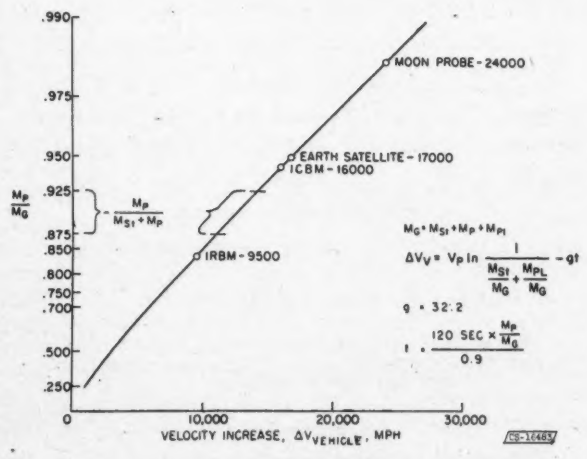


Figure 27

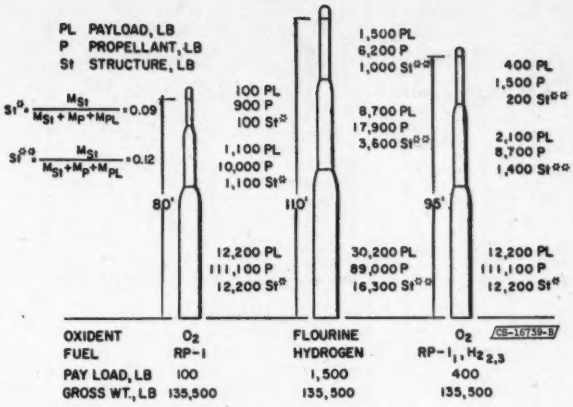


Figure 28
Rocket systems for moon probe

The maximum vehicle velocity for a single rocket stage is achieved with no payload. In this case:

$$\frac{M_P}{M_G} = \frac{M_P}{M_{St} + M_P}$$

Assuming a value for the ratio between 0.875 and 0.925, it is seen that a single stage rocket of the specific impulse assumed can achieve the IRBM mission but not the other missions listed.

Pending the successful use of higher specific impulse propellants, the required velocities are achieved by staging. Staged rockets are shown in Figure 28. In this case, as stated before, the payload of each rocket stage is the sum of the weights of the successive stages plus that of the final payload. With staged rockets, the velocity of the final payload is the sum of the velocity increases of the various stages with the velocity increase for each stage estimated according to Eqs. (2) or (3).

Assume a 100 lb payload is to be used as a moon probe. Assume that the required velocity increase is to be achieved in three stages of 8,000 mph each. Further, assume that for each stage the ratio M_P/M_G is 0.82, and that the ratio of $\frac{M_{St}}{M_{St} + M_P + M_{PL}} = 0.09$, leaving a ratio of M_{PL}/M_G of 0.09. These ratios will be held constant throughout the calculations for the $O_2 - C_8H_{18}$ rocket. (RP-1 is considered equivalent to C_8H_{18}.) Certain assumptions are made in regard to gravity losses ($g_e t$). The third stage of the $O_2 - C_8H_{18}$ rocket is computed to be as shown. The total third stage weight, including payload of 1,100 lb, becomes the payload of the second stage. Following through these calculations, the gross weight of the vehicle at takeoff becomes 135,500 lb. The desired velocity increase of 24,000 mph has been achieved, although the ratio of $M_{St3} + M_{PL3}/M_{G1}$ is 100 + 100/135,500 or 0.0015, instead of about 0.02 required (Figure 27) if a single stage rocket could have been built to do the job. (Ratios of payload to gross stage weight are, in general, appreciably higher than the value used here.)

A higher specific impulse propellant can be used to decrease the number of stages and the gross weight at launch to place the 100 lb payload in the proximity of the moon, or to permit a greater final payload for the

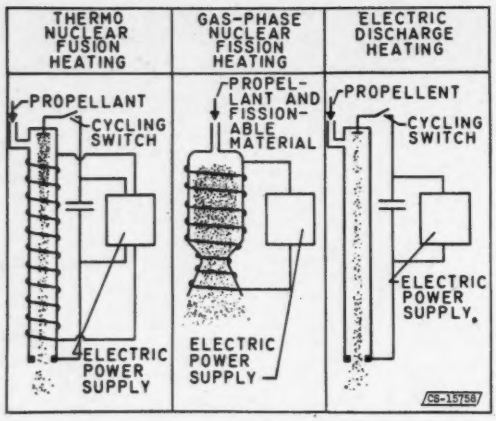


Figure 29
Thermal rockets using magnetically contained plasma as propellant

same gross weight at launch. The estimated results for the greater final payload are shown in Figure 28 for a three-stage rocket system employing fluorine-hydrogen as the propellant. In the computations, because of lower propellant density, the ratio of M_{St}/M_G is assumed to be 0.12. Because of the higher propellant velocity (specific impulse), the payload of the first stage is 30,200 lb, a two to threefold increase over that with the $O_2 - C_8H_{18}$ system. The increase is continued through the other two stages so that the final payload is 1,500 lb. The use of fluorine as an oxidant presents many problems. For instance, it is very corrosive. For this reason, a third rocket system is presented to show the kind of improvement that might be realized by using the upper two stages with hydrogen-oxygen as a chemical high-energy propellant. For these two upper stages M_{St}/M_G is again, assumed to be 0.12. In this case, the final payload becomes 400 lb.

The nuclear-thermal rocket permits still higher specific impulses. The analysis of the gains to be realized through its use are dependent on the amount of shielding required and on the temperature which the reactor can withstand. Certain gains that may be obtained will be briefly discussed later.

Means of increasing temperature limits

The thermal limitations imposed by the rockets shown in Figure 25 can be greatly lessened if rockets of the types shown in Figure 29 can be developed. In the first two examples the gas is heated by nuclear fission or fusion, heating taking place directly within the gas under such temperature conditions that a plasma exists,

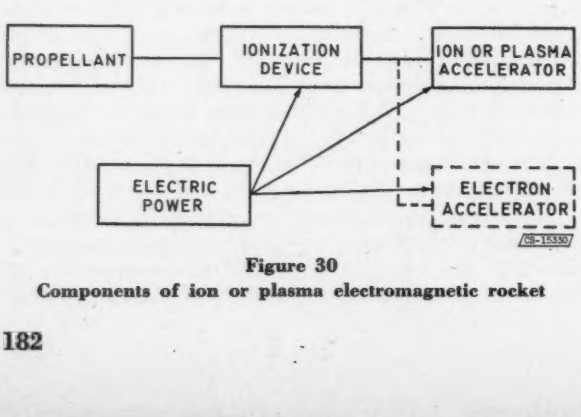


Figure 30
Components of ion or plasma electromagnetic rocket

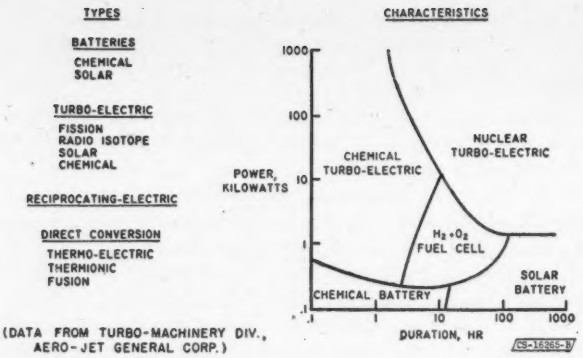


Figure 31
Electrical power generation

and the hot plasma is prevented from contacting the heating chamber walls by means of an electromagnetic field. In the third example electric discharge heating is used in which the hot ionized particles do not impinge on the chamber wall. The devices illustrated are simply meant to represent kinds of devices under consideration without regard to their present applicability. Other devices are also being considered, but they are very much in the research stage. Considerable research is needed to narrow the field down to those projects which warrant an intensive development effort.

Electric propulsion systems

The propulsion system in which the propellant is accelerated by means of an electric or electromagnetic field is shown diagrammatically in Figure 30. In this case, the propellant is fed into a mechanism (labelled "ionization device") and charged electrically. Assuming the charge is acquired by the removal of one or more electrons per particle, the propellant becomes either an ionized gas or a plasma, depending on whether or not the removed electrons are physically separated from the ions. For the ionized gas, an electric field is the accelerator; for a

$^*\Delta V_V$ = 25,000 MPH

ROCKET	PROPELLANT	$V_{PROP.}$, MPH	$\frac{M_P}{M_G}$	$\frac{HP}{F,\ LB}$
		THERMAL ROCKETS		
CHEMICAL	RP-1-O_2	6,500	.98	8.6
CHEMICAL	H_2-F_2	9,000	.93	12.3
NUCLEAR	H_2	26,000	.60	35.0
		ELECTRO-MAGNETIC ROCKETS		
ION	Cs^+	300,000	.09	409.0

$$V_V = V_{PROP.} \ln \frac{M_G}{M_G - M_P}$$

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*ΔV REQUIRED FROM EARTH SATELLITE TO MOON LANDING AND RETURN TO EARTH SATELLITE

Figure 32
Comparison of rocket propellant requirements for moon landing and return

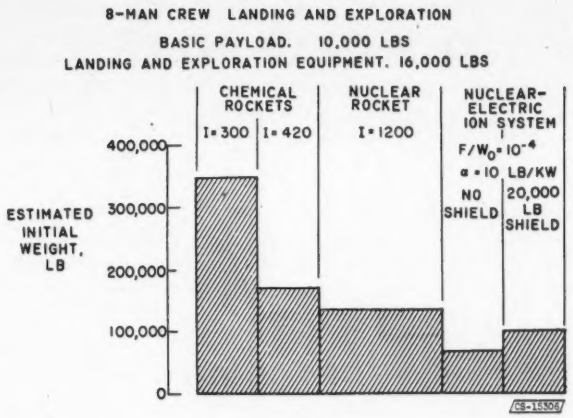


Figure 33
Round-trip to Moon

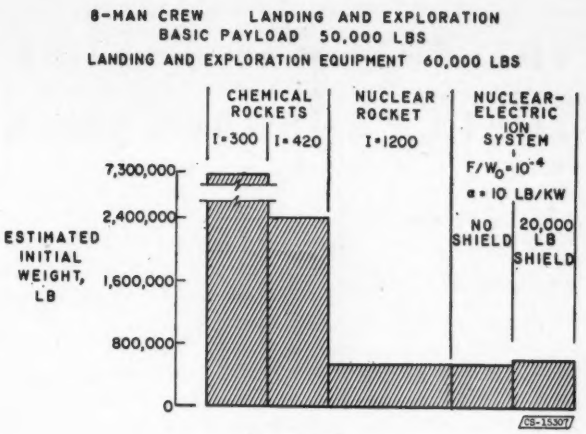


Figure 34
Round-trip Mars expedition

plasma, an electromagnetic field is the accelerator. In either case, propellant velocities of several hundred thousand miles an hour (specific impulses of 10,000 lb per pound discharged per second or more) can be attained.

To produce the required electrical power, various devices can be considered. Figure 31 lists estimated data for several chemical or nuclear powerplants. Again, additional research is required before definite conclusions can be drawn. The data emphasize the importance of power level and time of operation in making the correct choice.

Application of thermal or electric systems

In Figures 32, 33 and 34 comparisons are made of the results that might be obtained with the different spacecraft propulsion systems. Figure 32 assumes a total vehicle velocity change of 25,000 mph, the requirement to leave an earth orbit, land on the moon, and return to an earth orbit. This velocity change is about the same as required for the moon probe previously discussed. The propellant velocities for the thermal rockets are higher than those given in Figure 26, because higher expansion ratios are assumed. In addition, a greater amount of dissociation is assumed for the hydrogen propellant. The required ratio of propellant weight to gross weight for the given velocity change in a single stage is given in the third column. The propellant weight advantage accruing from the propellant velocity of 300,000 mph (specific impulse of 14,000 lb per pound per second) is evident.

In the last column are tabulated the values of horsepower per pound of thrust produced. As stated previously, for the chemical rockets, the power generation device is relatively light, being less than 10% of the total rocket stage weight. In regard to the nuclear rocket with a power to thrust ratio of 35 hp/lb, the picture is less clear because of uncertainties in regard to shielding required and operating temperatures. The electric propulsion systems present a definite problem because of the weight of the power generating system. The electric power required will probably be generated from nuclear energy. If a weight of 10 lb/hp of electric energy generated and transferred into jet power is assumed, the powerplant weight per pound of thrust generated is 4,000 lb/lb. Further, assuming a powerplant weight of 40% of the gross vehicle weight, the ratio of thrust to gross weight is 0.0001. With this thrust/weight ratio the electric system is appropriate for those situations in which the gravitational forces on the vehicle are of this order or less, or in which sufficient velocity has already been imparted to the vehicle to offset any gravitational force.

Estimated gross weights to go from an earth orbit to a moon landing and return to earth orbit are shown in Figure 33. In this case, the weight returned to earth orbit is 10,000 lb. The value of this weight has considerable influence on the ratio of initial to final weight. The specific impulse values, *I*, in pounds of thrust per pound of propellant per second, are listed for the thermal rockets. A thrust to weight ratio of 10^{-4} and a powerplant weight ratio of 10 pounds per kilowatt is specified for the nuclear-electric system. The data indicate the savings in gross weight over that with current chemical propellants that may be attained with either the chemical high-energy propellant (specific impulse 420 lb/lb/sec, that is propellant velocity approximately 9,000 mph) or with the nuclear systems. The initial weights listed are the required weight in an earth orbit at the start of the mission. Since the weight (mass) differences between the high-energy chemical and the nuclear system are reasonably close, the choice will depend largely on the rate of development of the two systems. Because of the low thrust to weight ratio with the ion system, the acceleration period to leave the earth orbit would be of the order of fifty days. For this reason, such a system will probably not be considered for this use.

Figure 34 shows estimated initial weights for a Mars expedition. In this case, the basic payload is 50,000 lb. The data indicate a marked advantage for the nuclear over the chemical system. The great payload, with the resultant increased power requirements, work in favour of the nuclear over the chemical system. Here, the choice between the nuclear thermal rocket and nuclear-electric system is not clear. Again, research is required to clarify the situation.

THE PHYSICAL NATURE OF THE PLANETS AND THEIR PROBABLE COURSE OF EVOLUTION†

by J. F. Heard*

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INTRODUCTION

I HOPE no one from that excellent province of Prince Edward Island will be offended if I tell a story about a young Islander who enlisted in the Air Force during the war and was sent to Manning Depot in Toronto. A tough sergeant gave the rookies a hard day of drilling and berating, and then yelled at them "Is there anyone here from the West?" The young Islander stepped timidly forward and said "Sir, I'm from Tignish".

When we come to consider the other planets we must be careful not to be from Tignish. We must neither assume that they must be like the earth with minor variations, nor that they are necessarily so unlike the earth that there is no use even considering the earth in relation to them. In studying the planetary system as a whole, we must exploit fully our knowledge of the earth, extrapolate that knowledge to the other planets and, at the same time, be prepared for marked differences.

We will find that two things which affect a planet more than anything else are its temperature and its size. Let us look at these briefly.

CHARACTERISTICS OF THE PLANETS

The primary factor affecting a planet's surface temperature is its nearness to the sun, for the surface does not get much heat from the interior. Nearness to the sun is not the only factor – rotation and atmosphere are also effective – but nearness is the primary factor.

Let us ignore Pluto, the outermost planet. There is good evidence that Pluto is an escaped satellite of Neptune, and in a way it doesn't count. In any event our knowledge of Pluto is very limited.

In Table 1 we see, among other data, the mean distances from the sun to the planets excluding Pluto. Relative to the earth, then, we can expect, other things being equal, extremely high temperatures on Mercury, moderately high temperatures on Venus, moderately low on Mars, extremely low on Jupiter, Saturn, Uranus and Neptune. We will see presently that what measurements we have of the planetary temperatures are reasonably consistent with these ratings.

In the table also are the diameters of the planets. Compare them with the sun whose diameter is 864,000 miles. Taken together, the total volume of the planets is only about 1/600 that of the sun's. We notice too that the planets divide rather neatly into two groups, the small "terrestrial" planets, Mercury, Venus, Earth and Mars, and the "giants" Jupiter, Saturn, Uranus and Neptune.

TABLE 1

PLANET	MEAN DISTANCE FROM SUN IN MILLIONS OF MILES	MEAN DIAMETER IN MILES	MEAN DENSITY IN g/cc
Mercury	36.0	3,010	5.46
Venus	67.2	7,610	5.06
Earth	92.9	7,918	5.52
Mars	141.5	4,140	4.12
Jupiter	483.3	86,900	1.35
Saturn	886	71,500	0.71
Uranus	1,783	29,500	1.56
Neptune	2,791	26,800	2.47

Now it would not seem too unreasonable to look for other similarities within these two groups, the warm, small terrestrial planets and the cold giants, and to expect other contrasts between the two groups.

With this in mind let us look at other less obvious physical properties.

One is density. By various devices astronomers have been able to determine the masses of the planets with about 1% accuracy. Thus we can get the densities or, if you like, specific gravities. Consulting the last column of the table, we find again similarities and contrasts.

The small warm planets are made of heavy materials, the big cold planets of light materials. Can we say what materials and can we say why the contrast?

If we ask a geophysicist about the earth's interior, he tells us with some confidence that there are two main parts which he recognizes from seismological evidence, the rocky mantle and the liquid iron core – with a sharp separation about half way down. The way in which the rock and the iron would be compressed under the tremendous pressures is consistent with the known average density figure of 5.5. We say, therefore, that we have a satisfactory "model" of the earth. We presume that models of the other terrestrial planets would be similar.

But how about the giants? Can we build satisfactory models? Not many years ago many astronomy textbooks presented models of Jupiter and Saturn, devised by Rupert Wildt of Yale University, which showed an

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outer shell of solid hydrogen, then a shell of ice and finally a core of rock. But a few years ago W. H. Ramsey of Manchester, W. C. De Marcus of Yale, Wildt himself and other astronomers began to realize that by the time one took account of the compression of these materials under the enormous internal pressures, these hydrogen, ice and rock models would be much too dense. When they looked for more suitable building materials they found that only the lightest materials, namely hydrogen and helium, would do for the main constituents. There appears to them to be no escaping the conclusion that Jupiter and Saturn anyway are mostly solid hydrogen, with some helium mixed in, and a bare dash of the heavier elements in a small core.

ORIGIN OF THE SYSTEM

If this recent conclusion is correct, we have another generality: small warm planets are made mostly of relatively heavy elements, iron, silicon, magnesium, oxygen, etc, and the cold giants are made mostly of the very lightest elements, hydrogen and helium. Does this make any sense in terms of the laws of physics and chemistry?

It does. In fact, if the planets have condensed from material like that composing the sun, this is just what we would expect. We know that the sun is about 70% hydrogen, 28% helium and 2% heavier elements. If we could take about 0.1% of the sun's mass of solar material and place it at the earth's distance from the sun, we could calculate that it would not all hold together under its self-gravitation at the temperature which it would assume in the sunlight. The helium would evaporate away almost entirely and the hydrogen all would evaporate except what might be locked to heavier elements by chemical combination; oxygen would remain in good proportion to its original amount because it locks chemically to so many elements. So the embryo earth would lose by evaporation about 99.8% of its original mass and would settle down with a composition vastly different from the sun – a composition favouring chemically active elements and heavy elements.

By way of contrast, if we were to take about 1% or 2% of the solar material and place it at the distance from the sun of Jupiter or Saturn, this larger embryo planet would, in the first place, have a stronger gravitational hold on its materials and, in the second place, have less solar heating. It would therefore be subject to less evaporation loss, and such loss would be less selective as between the heavy and light elements. Such an embryo planet might settle down as a cold planet predominantly composed of hydrogen and helium as we believe Jupiter and Saturn to be.

This plausible view of how the present planets might have developed is part of a theory first proposed by the German physicist, W. C. von Weizsacker, and modified by the American astronomer, Gerard Kuiper. Twenty years ago most astronomers visualized the planets condensed from solar material torn from the sun by a collision or near-collision with another star. Such a view would have made our solar system a freak of nature, perhaps unique. Kuiper's view, however, is that the planets condensed from the outlying portions of the same solar nebula from which the sun was formed. If this is correct, then we could easily believe that one star in a hundred, or in a thousand, might be accompanied by a system of planets; in which case there would be many millions of planetary systems even in our own galaxy, let alone in the millions of other galaxies which we know about.

At the present time we cannot test observationally this idea of the multiplicity of planetary systems. Even a large planet accompanying the closest star would be too faint to see with the world's best telescope. In fact, we foresee no way of making the observational test in the future, and it may be that we will long be dependent upon the plausibility argument based upon knowledge of the origin of our own system. We see, therefore, the importance of improving that knowledge.

So far, we have dealt with generalities among the planets. We have understood the two main classes of planets in terms of a theory of origin which would seem to make planetary systems fairly common. If we are interested in the question of life on other planets, in this system or in others, we must now examine the planets in more detail.

LIFE ON THE PLANETS

What is it about the earth that favours the existence of life? Primarily it is the presence of water in a temperature range which permits it to exist in the liquid state, and the presence of carbon dioxide and oxygen in the atmosphere. If we would be content with plant life we could probably rule out the need for much oxygen, since the earth's atmospheric oxygen is believed to be a result of plant life. On what planets can we expect to find the necessary conditions – water, moderate temperature and carbon dioxide?

Not on Mercury. There is no evidence of any atmosphere at all – in fact, if there were such evidence we would find it hard to believe, the planet being so small and so close to the sun that even the heaviest gases would evaporate rapidly away. Mercury always faces the same side to the sun, and the temperature on the bright side has been measured at 660°F, while on the cold side it must be close to absolute zero.

Not on the giant planets. Their measured temperatures range from −240°F for Jupiter to −370°F for Neptune. They have atmospheric components which have been identified as hydrogen, ammonia and methane. Let us rule them out. This leaves Venus and Mars.

Venus is difficult to understand because it is completely and perpetually enshrouded in dense clouds. Recent investigations indicate that the temperature of the cloud tops is about 100°F. Spectroscopic evidence shows the existence of copious quantities of carbon dioxide above the cloud tops, but no water vapour and no oxygen. Nitrogen and argon may also be present in the dense atmosphere that buoys up the clouds, and it appears probable that the total atmosphere is at least as great as that of the earth. Recent analysis of thermal radio noise from Venus calls for a ground temperature of about 500°F – near the melting point of lead. The material of the clouds is still in doubt. We can say more about what it is not than what it is. It is not water because if it were, then water vapour would show in the spectrum of the planet. It is not carbon dioxide snow (dry ice) because the measured temperature is too high. Some believe that the clouds are of dust billowing up in the strong winds from the desert-dry, sand-blasted sur-

face of the planet. Kuiper, on the other hand, believes that the clouds consist of particles of carbon suboxide (C_3O_2), a yellowish compound which under earthly conditions is unstable.

In any event, unless we are entirely misled about conditions on Venus, we must rule it out as an abode of life. The high temperature and the absence of water are reasons enough.

Perhaps we should pause to wonder why two planets as alike as Venus and the earth in size and in distance from the sun should be so different as to atmosphere. What are the differences again? (a) On earth plenty of atmospheric oxygen, on Venus little or none. Not hard to understand, though, if, as we believe, plant life has given rise to the earth's atmospheric oxygen, and Venus has had no plant life. (b) On earth little atmospheric carbon dioxide, on Venus much. Again not hard to understand if Venus never had plant life to use up its carbon dioxide. (c) On earth lots of water, on Venus none. A little harder to understand. We might ask where did the earth's water come from? Is it primitive or secondary? There is an excellent reason to believe that it is secondary; neon, with nearly the same atomic weight as water's molecular weight, is very rare on earth compared with its cosmic abundance – at some earlier warmer stage in the earth's history neon apparently escaped almost entirely. What water vapour existed then must also have escaped. The present water must have belched forth as steam from the interior at a later cooler stage when it could be retained. Great quantities of carbon dioxide must have done the same, but this has been used up almost entirely by the ancient luxuriant plant life which broke down the carbon dioxide into the oxygen which we are now living on and the coal and oil which we mine from the earth. Why didn't Venus produce oceans of water by vulcanism? Was Venus too hot to retain the water? We don't know. However, we notice that all the differences between Venus and the earth can be made to hinge on the failure of Venus to produce oceans.

Mars has always intrigued us because at least we can see down to its surface. Not very clearly, though, because Mars is hazy – evidence already of at least a thin atmosphere, its pressure estimated at about a tenth the earth's, or equivalent to the pressure at an altitude of ten miles. There are clouds occasionally, thin clouds, some yellow, some white. The yellow ones may be dust, the white ones water. There are white polar caps that come and go, north to south, in the two-year seasonal cycle of Mars just as though they are thin deposits of snow, which they probably are. Spectroscopically Mars shows about twice as much atmospheric carbon dioxide as the earth, but no water vapour and no oxygen – at least not enough to disentangle from the earthly oxygen and water vapour which we must look through – in any event, less than 0.1% of the earth's. The major constituent of Mars' thin atmosphere is probably nitrogen which, unfortunately, is spectroscopically undetectable.

Martian ground temperatures have been measured by several methods. In a south tropical region in summer the daytime temperature is 86°F and the night-time temperature –15°F; at "our latitude" on Mars in winter the noontime temperature is –60°F. It is definitely colder on Mars, but not cold enough, we think, to inhibit life altogether. More serious is the extreme dryness – only enough water vapour to give the occasional thin cloud and a bit of frost at the poles in winter – and, as far as animal life is concerned, the almost complete lack of oxygen.

The permanent surface markings of Mars are hard to interpret and have given rise to much conjecture. Many observers have seen fine markings, the so-called canals, while other observers deny their existence; in any event we can be sure that they are not man-made for the transportation of water. On the other hand large markings definitely exist – grayish green areas overlying the general rusty colour of the planet. These greenish areas change shape and colour with the seasons, but always come back in the same places. In view of the frequent yellow dust clouds, we must almost believe that something keeps replenishing the green colour. It has often been suggested that the green is vegetation, but the evidence has been inconclusive. Dr. Peter Millman at the David Dunlap Observatory showed on spectroscopic evidence in 1938 that the green was, in any event, not the green of the chlorophyl of leafy plants. It was suggested that perhaps it was a type of lichen or arctic moss. Recently there has been more positive evidence of vegetation. W. M. Stinton at Harvard has found in the infrared spectrum of the green areas some features which are found only in the reflection spectra of organic hydrocarbons. Thus the evidence for vegetation on Mars has been strengthened, though I doubt if we can admit that the point is proved.

If we do accept the idea of vegetation on Mars, are we to believe that these lichens are the last survivors of Martian plant and animal kingdoms which dwindled as the planet became less and less hospitable, or are we to accept the improbable notion that spores from the earth have been borne across interplanetary space to take root on Mars? Until we can have a better look at Mars and find evidence of oceans in the distant past, it will be difficult to believe that life ever originated on such an inhospitable planet.

CONCLUSION

I hope we have avoided being from Tignish. If we *have* been open-minded, I think we have concluded that the earth is the only domain of intelligent life – perhaps of life at all – in this planetary system. We have seen that life has been no sideshow on this planet, but has played a role in the evolution of its atmosphere and surface. We hope that further more detailed study of our planetary system may permit us to say with greater certainty whether or not there are other planetary systems. If there are, it is hard to believe that intelligent life has not come to some of the favourably endowed planets. But whether or not we will ever really know – that is another question.

EMERGENCY ESCAPE FROM TANDEM-CREWED AIRCRAFT†

by R. E. F. Lewis*

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SUMMARY

The paper considers the nature and duration of escape warning and action in tandem-crewed aircraft with respect to escape incidents in which little time is available for the escape, particularly those occurring near to the ground.

Experienced pilots and navigators performed escape sequences in a full-scale mock-up of a tandem-crewed supersonic aircraft equipped with Martin-Baker ejection seats.

Measurements were taken of escape control operation, crew patter and movement throughout the sequences by an oscillograph, magnetic tape and cinephotograph record.

The main findings were:

(a) The faster of the two escape sequences, with patter, took an average of 6.8 sec to complete, the maximum time taken being 11 sec.

(b) Warning, without patter, using a visual/audio system (warning light plus horn), took significantly less time, but is thought to be normally used only as a supporting warning.

It is concluded that the escape times measured within the limits of this study are excessive and that under actual conditions escape time will be lengthened.

In view of these conclusions, it is recommended that:

(a) The ejection seats in tandem-crewed aircraft be so linked together that the pilot by operating one control ejects both the observer and, in turn, himself. Such a linked system would necessitate complete automatic restraint prior to ejection for the observer and, in addition, an override that would permit independent observer escape.

(b) An attempt be made to establish by experiment a brief and effective verbal warning.

(c) The significance of short periods of time in escape be studied more closely during the compilation of accident reports, particularly for aircraft carrying more than one occupant.

INTRODUCTION

One of the important factors affecting emergency escape from aircraft is the time taken by aircrew to abandon the aircraft once the flight condition demanding escape has been reached.

A high proportion of accidents occur during landing and takeoff. In general the time taken to escape becomes increasingly critical the nearer the aircraft is to the ground.

There have been accounts by World War II pilots of escape from single-place aircraft in which delays due to the physical difficulties of disengaging the body from the cockpit were emphasized[1]. Delays of this kind have been minimized through the evolution of the ejection seat[2, 3]. The pilot escaping from many current high performance aircraft has only to operate one control to initiate an automatic escape sequence. Then, (a) the canopy is jettisoned, (b) the pilot is ejected, his legs having been restrained, (c) the seat falls stabilized, (d) the occupant separates from the seat at appropriate speed and altitude, (e) the personal parachute is deployed. This automatic sequencing has unquestionably saved the lives of many aircrew because escape time for a single ejection has been minimized. There is, however, another escape delay problem which is peculiar to aircraft carrying more than one crew member. This is the problem of delay caused by the communication of the warning to escape, from the pilot to the other occupant(s).

It is the purpose of this paper to report a study of the time taken by tandem-placed aircrews to complete their escape.

PROCEDURE

The tests were conducted in a full-scale mock-up of a supersonic tandem-crewed aircraft. The cockpits were fully instrumented and equipped with all the associated controls, switches etc, together with Martin-Baker Mk. 4 ejection seats (see Figure 1). For the purposes of these trials a seat plan alternative D firing ring was attached to the seats.

Measurement of escape time commenced when a red warning light in a central position on the pilot's instrument panel was switched on by the experimenter. This

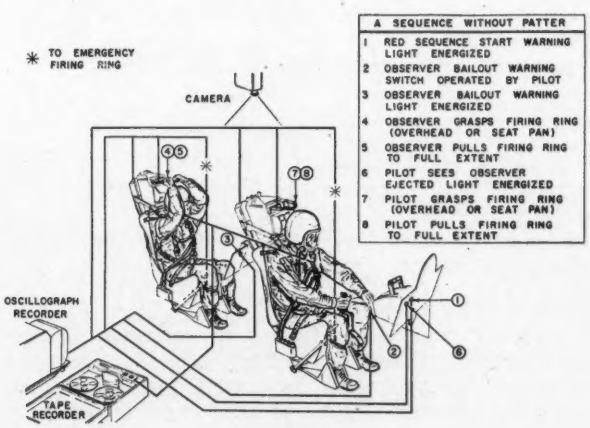


Figure 1
Escape delay study — test situation and apparatus

†Received 26th January, 1959. This work was carried out during the author's appointment with Avro Aircraft Limited.
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light represented the occurrence of the flight condition demanding escape. Pilots were instructed to initiate their escape sequence upon seeing the red warning light – therefore their subsequent actions were timed under ideal conditions as the pilot and observer were anticipating the sequence[a]. A sequence was considered to be complete when the pilot, the last to eject, had, so-to-speak, "cleared" the fuselage of the aircraft.

Instrumentation

As stated above, the escape warning from pilot to observer was conveyed by either verbal or visual means: the intercommunication system, the red master warning light, and the escape warning lights were energized for this purpose.

The escape warning lights were located in a central position in each cockpit. The "Bail-out" Light in the observer's cockpit was red and was lit by the operation of a switch, termed the Observer Bail-out Switch, in the pilot's cockpit. The action of ejection by the observer energized a second light (green) on the pilot's instrument panel, which indicated to the pilot that the observer had ejected.

At the start of each sequence, when the pilot's red master warning light came on, three synchronized and continuous records of events in time within the sequence were commenced. These records were:

(1) A cinephotographic record at 64 frames per second. The camera was positioned above the cockpits and recorded head, trunk and arm movements throughout the sequence.
(2) A magnetic tape record of verbal communication.
(3) An oscillograph trace record showing the occasion of the following events in time:
   (a) Sequence-start-warning light switched on.
   (b) Pilot operation of the switch lighting the observer's "Bail-out" Light.
   (c) Observer grasping either the overhead or seat pan D firing ring.
   (d) Observer pulling firing ring to full extent.
   (e) "Observer ejected" Light on in pilot's cockpit.
   (f) Pilot grasping either the overhead or seat pan D firing ring.
   (g) Pilot pulling firing ring to full extent.

The time taken for the canopies to open and the time taken for the seats to travel up the rails to clear the fuselage were calculated separately (see Results).

Subjects

Six qualified aircrews, 6 pilots and 6 observers, acted as subjects for the study. These included RCAF pilots and observers, test pilots and flight test observers. All were experienced on the Avro CF-100 aircraft, and all had received instruction in the operation of the Martin-Baker ejection seat.

Personal flying equipment

Throughout the sequences each subject wore personal equipment designed for flight in high performance aircraft. This equipment included a pressure helmet, anti-g suit, pressure vest and pressure valve. The clothing was worn to simulate as nearly as possible actual conditions experienced whilst flying, and to enable an estimate to be made of any restrictions to movement that the personal equipment might impose.

Each subject was strapped firmly to the seat by the safety harness, and breathed 100% oxygen with the pressure vest inflated to safety pressure of 8-10 mm Hg.

Instructions

A written briefing describing the purpose and nature of the trials was issued to the test subjects one day prior to their participation (see Appendix I).

Before entering the cockpits the subjects were briefed verbally. Finally, when the crews were seated in the cockpits, and just prior to the commencement of each sequence, the actions to be taken by the subjects were again described.

At the start of each sequence the pilot sat with his right hand grasping the control column which was in the neutral position – his left hand was placed on the throttles which were open.

Crew actions and procedure during the four sequences tested

Sequence A – Without patter

(i) The sequence-start-warning light in the pilot's cockpit was switched on.
(ii) The pilot moved his left hand back and down to the Observer Bail-out Switch.
(iii) The pilot operated the Observer Bail-out Switch.
(iv) The observer saw that the "Bail-out" Light was on.
(v) The observer grasped and pulled his overhead D firing ring.
(vi) The pilot saw that the "Observer ejected" Light was on.
(vii) The pilot grasped and pulled his overhead D firing ring.

Sequence B – Without patter

This sequence differed only from Sequence A in that both pilot and observer "fired" the seat by means of a seat pan D firing ring instead of the overhead method.

Sequence C – Using standard service bail-out patter

(i) The sequence-start-warning light in the pilot's cockpit was switched on.
(ii) The pilot then said, "Prepare to abandon aircraft, prepare to abandon aircraft. Eject, eject". As he gave this verbal warning he prepared to operate the Observer Bail-out Switch as in Sequence A (ii) above. He operated the switch whilst saying, "Eject, eject". No verbal response was required from the observer. The remaining actions required were as in Sequence A.

Sequence D – Using spontaneous patter

For this sequence a verbal acknowledgment was required from the observer of the verbal warning from the pilot (see Appendix II). When the pilot heard the acknowledgment he *then* operated the Observer Bail-out Switch. Otherwise the actions required were as in Sequence A.

Throughout these trials the observer was the first to eject. Other possible sequences were not tested, for

[a]Under actual escape conditions additional delays could occur—see Discussion.

TABLE 1

TOTAL ESCAPE TIMES — ALL SEQUENCES (SECONDS)

Crew	Sequence A Trials			Sequence B Trials			Sequence C Trials			Sequence D Trials		
	1	2	3	1	2	3	1	2	3	1	2	3
1	3.81	3.14	2.56	2.37	3.60	3.57	7.52	6.23	6.67	7.03	8.38	4.86
2	8.53	8.73	6.68	6.10	6.53	6.90	10.32	11.03	9.90	11.50	8.58	8.32
3	4.27	3.28	3.27	3.28	3.75	3.32	7.82	4.35	4.84	7.60	6.19	6.06
4	3.47	3.10	3.08	3.85	3.60	2.74	7.20	4.54	5.36	8.53	7.55	6.85
5	5.57	4.48	4.68	4.30	3.83	4.33	6.71	5.65	6.30	8.07	6.15	6.46
6	6.72	3.79	4.58	4.38	4.40	4.25	7.62	6.41	6.17	8.02	7.44	5.82
Mean	5.3	4.4	4.1	4.0	4.2	4.0	7.8	6.3	6.5	8.4	7.3	6.3

Canopy opening time, and time for the ejection seat to travel up the rails was calculated* (1.4 seconds) and must be added to the above means to determine a representative 'escape time'.

*Average single canopy opening time 0.5 second. Seat rail travel time maximum 0.2 second.

under actual escape conditions the pilot may wish to attempt to control the aircraft whilst the observer ejects.

Trial design

It was considered that no special escape practice was necessary prior to the commencement of the recorded trials, since the aircrews acting as subjects were currently engaged in flying in the CF-100 which is equipped with Martin-Baker ejection seats. Each crew performed each of the four sequences in random order. This procedure was repeated twice more with different random order; thus each crew participated in 12 sequences, a total of 72 sequences being measured during the study.

Analysis

The oscillograph record gave the most useful measure of elapsed time during the sequences. These measurements were made to the nearest 0.01 second.

RESULTS

The total escape times for all crews and sequences are shown in Table 1. Figure 2 summarizes the evidence. An analysis of variance of the escape times was performed (see Appendix III).

Clearly the most important finding is that, under optimum conditions, an escape sequence using verbal communication can take as long as 11 seconds, and in most cases longer than 5 seconds even with practice (Table 1 and Figure 3).

A comparison between the mean scores of the combined Sequences A, B (without patter) and the combined C, D (with patter) showed a highly significant difference.

There was improvement with practice which was statistically significant but small in magnitude. There were large differences between the crews in overall escape times.

Time for an individual occupant to complete an escape was obtained from the component times within sequences. The mean times for the pilot to complete ejection after the "Observer ejected" Light came on are shown in Figure 4 and, when compared with the results for the tandem crews, the delaying effect of communication can be seen.

The time taken by pilots from the start of the sequences to reach and operate the Observer Bail-out

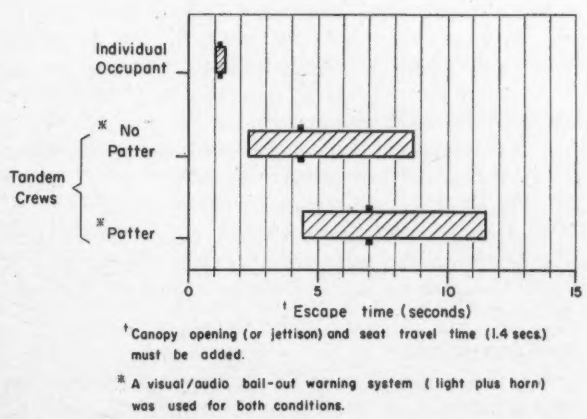


Figure 2

Range of escape time measured for crews with and without patter

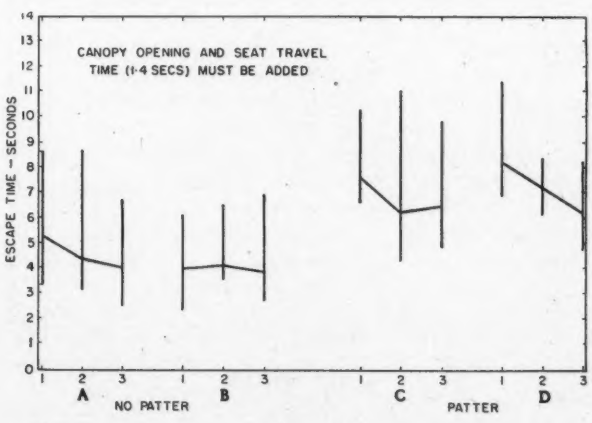


Figure 3

Escape times — means and ranges for all sequences

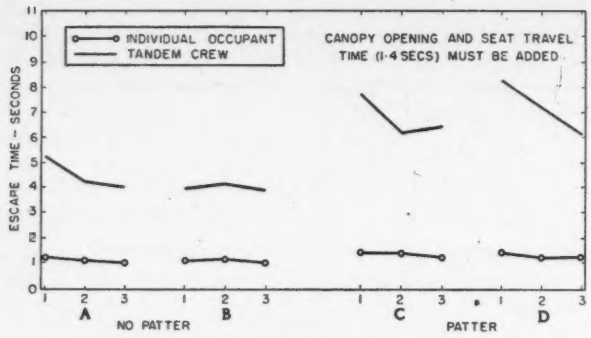


Figure 4

Differences between tandem crew and individual occupant — mean escape times

Switch (Figure 5) was approximately 2 seconds. This seemed excessive. From inspection of the cine record it was found that all pilots chose to identify visually the position of the switch before operating it. The location of the switch in a bank, together with four others which were identical, presumably necessitated this visual identification and caused a slight additional delay.

The statistical comparisons noted above must be considered in relation to the practical escape situation. These data represent escape times measured under ideal conditions. The improvement obtained by omitting patter is, though statistically significant, of little practical value since in practice a verbal warning will almost certainly be used.

It has been shown that under ideal conditions escape time is unduly long — particularly for some crews. Under actual escape conditions, these times are most unlikely to be shorter and quite probably will at times be very much longer.

DISCUSSION

In this study an attempt was made to measure the time taken by tandem-placed two-man crews to perform escape sequences, which consisted of (a) recognition of the escape warning by the pilot, (b) communication between the men, and (c) operation of the ejection seat firing controls. The tests were anticipated by the crews and were performed under ideal conditions.

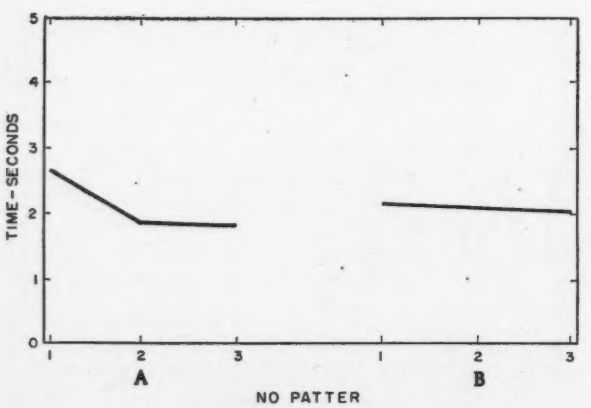


Figure 5

Pilot time to reach and operate the Observer Bail-out Switch, from the start of the sequence

Delays

However, in actual escapes, escape time may very well take longer, since there are other factors which could cause additional delays.

The basic components in time which may cause delays in actual escapes may be described under three main headings.

Appraisal time

When emergencies occur which may require escape by the aircrew, the pilot will first appraise the situation. If it is not immediately obvious that an escape must be made, the appraisal should be followed by an attempted correction by the pilot, for he is trained to perform corrections as a major part of the piloting task. Both appraisal and correction periods will take time.

Warning time

In certain flight conditions demanding escape, e.g. loss of control, control system failure, the order to escape may be completely unexpected by the observer. The pilot, in flying the aircraft, is continually making control adjustments to which he expects definite aircraft responses. The observer, however, performs his task whilst exposed to only the aircraft responses (g, attitude change etc), often without knowledge of when they will occur. Therefore, when the pilot receives an unexpected aircraft response to a control movement, or the aircraft suddenly behaves strangely, the pilot is quick to recognize it. On the other hand, the observer may at times receive his first indication of the emergency when the pilot issues the escape order.

Because of the unexpected nature of the message[4], and if spoken by the pilot under stress[5, 6] with lessened intelligibility[7], the observer may ask for the message to be repeated — this will of course take time.

Presumably most pilots and observers who fly as a crew agree that, wherever possible, a verbal warning will be used by way of explanation. This would seem to be substantiated by the warnings chosen by the crews in this study (Appendix II).

Another important factor which affects both warning and action periods is the observer's attitude toward escape. Whereas some observers may be poised ready to eject with alacrity, others may naturally hesitate before resorting to escape by ejection.

In actual escapes, escape time may be extended for the following additional reasons:

(a) The observer may not agree with the pilot's order to escape and may debate the issue.

(b) The observer may refuse or fail to eject.

Incidents have occurred in which pilots have met this type of response to their order to eject. Clearly, delays of this kind can reduce the chances of survival for both occupants.

Crew action time

The delays which may be attributed to crew action during escape have been reduced largely through the efforts of aeronautical engineers specializing in the design of ejection seats. As stated earlier, the pilot and observer each has only to operate one escape control to

initiate a series of automatically sequenced events. However, the position of the ejection seat firing control(s) may yet be improved for use in conditions in which acceleration forces are excessive. Similarly, any visual/audio warning control should be carefully positioned if it is to be included in the escape system[b].

Accidents in which escape time was critical

In this paper, considerable emphasis has been placed on the significance of time in escape – particularly escapes which are known to occur at relatively low altitude[5]. This point is best illustrated by two accidents involving high-performance jet aircraft carrying tandem-placed two-man crews[6].

(1) The first incident concerns an aircraft which fell in an inverted spin from a height of approximately 5,000 ft above water. It has been calculated that the crew had some 25 seconds in which to escape, assuming that no spin recovery should be attempted at that low altitude. Just before the aircraft struck the water the observer ejected. The pilot did not eject. Both were killed.

In this incident, it is obvious that the pilot, upon entering the spin, should have immediately ordered abandonment. But, in the writer's opinion, it seems reasonable to suppose that he attempted a spin recovery. It is possible also that, during the attempted recovery, he concentrated solely on the recovery and said nothing to his observer. Then, perhaps recognizing that too much height had been lost, he commenced to warn the observer to eject.

(2) The second incident concerns an aircraft which, during a low level high speed run, exceeded the g limitation stated for the aircraft.
From the time at which the aircraft wingtips failed structurally to the time at which the aircraft struck the ground, some 10 seconds elapsed. After 5 seconds the pilot ejected, but unfortunately did not completely separate from the seat and was killed. The observer remained in the cockpit and was killed in the crash.

In this accident very little time indeed was available for the escape; the pilot probably issued a brief bail-out order and then ejected. The observer may not have ejected for any one, or a combination of, the reasons previously mentioned.

'Linked escape' — A method of reducing escape times for tandem crews

Clearly there are times when it is most desirable that escape time be minimized. One method of positively reducing escape time is to so link the seats that the pilot, by operating one control, ejects the observer and, in turn, himself. Such a linked system could reduce total crew escape time to 2.5 seconds. It would, however, be necessary to provide complete automatic restraint for the observer prior to ejection in order that he be properly positioned for ejection. Furthermore an override permitting independent observer escape would be a necessary part of the system.

[b]The Observer Bail-out Switch on the aircraft in question has now been mounted alone on an otherwise clear panel face. It is hoped that the risk of wrong switch selection has now been reduced and switch operating time minimized.

The problem area in the design of a linked system lies in engineering the automatic observer restraints. Otherwise it is understood that there should be no serious design problems, and the reliability of the system should not be unduly affected.

Linked escape would be used by the pilot when it is obvious to him that the crew must abandon the aircraft in the shortest possible time. On other occasions, when more time is available, the conventional method of independent ejection could be used, or the linked system after the pilot has issued a warning to the observer to prepare himself for pilot initiated ejection.

To refer again to the two accidents described previously, it seems reasonable to suppose that had a linked system been installed in these aircraft:

(a) All four men would probably have been ejected.
(b) All four men would probably have been ejected sooner with a better chance of survival for three, if not all four, of them – the possible exception being the pilot who did not separate completely from the seat.
(c) Both pilots would have been required only to make and execute the decision to escape – no order to escape to the observer would have been necessary.

An advantage of linked ejection from higher altitude would be the close proximity of the pilot and observer during and after the parachute descent; the rescue problem would be eased and, in the event of injury upon landing or the need for survival in sparsely inhabited areas, the crew could again function as a team.

CONCLUSIONS AND RECOMMENDATIONS

The results obtained in this study suggest that escape sequences for a tandem crew can take an excessive period of time when considered in relation to low level incidents demanding escape.

In the light of this evidence it is recommended that in tandem-crewed aircraft the ejection seats be so linked together that the pilot, upon deciding that the *crew* must escape immediately, operates the firing control of his seat which will automatically eject the observer and, in turn, himself. Such an arrangement could reduce total escape time for both occupants to approximately 2.5 seconds.

However, in order that the observer be properly positioned for ejection, an automatic restraint for the observer would be a mandatory component of a linked system. Furthermore, the observer should be provided with an override which would enable him to eject alone (a) in case where there is ample time for the escape, or (b) should the pilot be incapacitated, e.g. by anoxia. Certainly the design of a linked seat system should be such that the reliability of the escape system is maintained at the highest level.

It seems reasonable to conclude that the standard escape patter used in this study is unreasonably long where very little time is available for the escape, and it is recommended that a brief and effective warning be determined by experiment for use in current tandem-crewed jet aircraft.

The significance of short periods of time in escape, particularly for aircraft carrying more than one crew member, should be studied more closely during the compilation of accident reports. One approach might be to

record all jet aircraft intercommunication on recoverable miniature tape recorders. Valuable information could thus be obtained that in time would provide more details about crew behaviour during *actual* escapes.

ACKNOWLEDGMENTS

This study was conducted using the test facilities of Avro Aircraft Limited and it is a pleasure to acknowledge the support given to the project by Mr. R. N. Lindley, Chief Engineer of that Company.

The writer also wishes to acknowledge the assistance given by the Royal Canadian Air Force Institute of Aviation Medicine through the services of Flight Sergeant R. M. Rynard.

Dr. J. Ogilvie of the Defence Research Medical Laboratories advised the late Mr. W. A. K. Chambers of Avro in his work on the statistical analysis.

The pilots and observers who acted as subjects and the Avro Test Department deserve especial thanks.

APPENDIX I

INSTRUCTIONS FOR AIRCREW PARTICIPATING IN THE ESCAPE TRIALS

The purpose of these tests is to obtain data that may assist in preparing a satisfactory escape sequence. The following points have been considered and instrumentation installed to record them:

(a) The physical movements of the aircrew during sequences.

(b) Elapsed time intervals for each step of an ejection sequence.

(c) Total elapsed time for a complete sequence.

(d) Alternative escape sequences.

The following describes the escape sequence for the pilot and observer.

General

It is important that you understand these instructions. If you have any questions as to their meaning ask for clarification from the test personnel. Instructions for each sequence will be repeated to you when you are in the cockpit prior to each sequence.

Please do not discuss your actions in these trials with other participants until they have completed their test. Such discussion may affect your results.

Pilots

The following will list the actions required by the pilot for four different escape sequences.

Sequence A (no patter)

(1) The timed sequence will begin when the red warning light comes on in the front panel of the pilot's cockpit.

(2) The pilot immediately operates the Observer Bail-out Switch. This switch is located on the left hand console immediately aft of the throttle box.

(3) The next action of the pilot is initiated by the green "Observer Bailed-out" Light coming on. This light is located beside the red warning light described in Item (1) above.

(4) The pilot, upon seeing the green light, shall take a firm grip on his overhead face blind and pull down as in a normal bail-out. This action completes the pilot's portion of the escape sequence.

Sequence B (no patter)

(1) As in (1) above, the sequence begins with the red warning light coming on.

(2) The pilot selects "Observer Bail-out" as in (2) above.

(3) The next action by the pilot is initiated by the green "Observer Bailed-out" Light coming on as in (3) above.

(4) The pilot, upon seeing this green light, shall take a firm grip on the ejection handle located between his legs on the front face of the seat pan. He must then pull upon this handle to complete his portion of the escape sequence.

Sequence C (with patter)

(1) As in A and B (1) above, the sequence begins with the red warning light coming on.

(2) The pilot verbally warns the observer, "Prepare to abandon aircraft – prepare to abandon aircraft" – Switches on observer's "Bail-out" Light simultaneously saying, "Eject – Eject".

(3) The next action of the pilot should be initiated by the green "Observer Bailed-out" Light coming on as in A and B (3).

(4) The pilot, upon seeing the green light, shall brace himself, take a firm grip on the overhead face blind, and pull down on the handle to complete his portion of this ejection sequence.

Sequence D (with patter)

(1) As in A, B and C the sequence begins with the red warning light coming on.

(2) The pilot warns the observer verbally using his own words, but not switching on the observer's "Bail-out" Light until his command has been understood by acknowledgment from the observer.

(3) The next action by the pilot is initiated by the green "Observer Bailed-out" Light coming on, as in A, B and C (3) above.

(4) The pilot, upon seeing the green light, shall brace himself, take a firm grip on the overhead face blind, and pull down on the handle to complete his portion of the ejection sequence.

Observers

The following lists the actions required by the observer for four different escape sequences.

Sequence A (no patter)

(1) The timed sequence for the observer begins when his "Bail-out" Light comes on. This light is located in the centre of the observer's front panel.

(2) The observer, upon seeing this light, shall brace himself, take a firm grip on his overhead face blind and pull down as in a normal bail-out.

Sequence B (no patter)

(1) As in Sequence A (1) above, the sequence begins when his "Bail-out" Light comes on.

(2) The observer, upon seeing this light, shall take a firm grip on the ejection handle located between his legs on the front face of the seat pan. He must then pull up on this handle to complete his portion of the escape sequence.

Sequence C (with patter)

(1) Upon hearing the pilot saying "Eject – Eject" and seeing the "Bail-out" Light come on simultaneously, the observer bails out as in Sequence A (2) above.

Sequence D (with patter)

(1) Upon understanding the pilot's verbal bail-out warning, the observer must acknowledge verbally; he will then see his "Bail-out" Light come on. He can then bail out as in Sequence A (2) above.

APPENDIX II

The "spontaneous patter" used in Sequence D by each crew was transcribed from the magnetic tape recorder, and is reproduced below.

CREW 1

Trial 1–Pilot: "O.K. Bob, prepare to abandon the aircraft."
Observer: "O.K. Pete."

Trial 2–Pilot: "O.K. Bob, prepare to abandon the aircraft."
Observer: "O.K. Pete."

Trial 3–Pilot: "O.K. Bob, stand by to eject.'
Observer: O.K. Pete. Right."

CREW 2

Trial 1–Pilot: "Something's wrong here Alf. Bail out."
Observer: "Roger, Stan. Bail out."

Trial 2–Same as above.

Trial 3–Same as above.

CREW 3

Trial 1–Pilot: "Observer, aircraft in trouble. Bail out."
Observer: "Understand – bail out."

Trial 2–Same as above.

Trial 3–Same as above.

CREW 4

Trial 1–Pilot: "We're on fire. We're on fire. We must eject."
Observer: "O.K. Ready to eject."

Trial 2–Pilot: "We've got to get out. We're on fire. Eject. Acknowledge."
Observer: "Ready to eject."

Trial 3–Pilot: "Fire. Fire. Eject. Eject."
Observer: "Ready to eject."

CREW 5

Trial 1–Pilot: "Hey, Duane. The wing fell off, let's get out of here."
Observer: "Roger. Prepared to bail out."

Trial 2–Pilot: "Hey Duane, we're on fire. Bail out."
Observer: "Right. Ready to go."

Trial 3–Pilot: "Hey, Duane. Get out."
Observer: "Right. Ready to go."

CREW 6

Trial 1–Pilot: "We're in trouble. We're in trouble. Bail out. Bail out."
Observer: "Roger. Ready to go."

Trial 2–Pilot: "Bail out. Bail out."
Observer: "Roger. Ready to go."

Trial 3–Pilot: "We're in trouble Geoff. Bail out. Bail out."
Observer: "Ready to go."

APPENDIX III

ANALYSIS OF VARIANCE

	D.F.	S.O.S.	Mean Sq.	V.R.	5%	1%
Crews	5	1,216,071	243,214.2	47.0	2.53	3.70
Sequences	3	1,441,907	480,635.7	92.9	2.92	4.51
Trials	2	173,073	86,536.5	16.7	3.32	5.39
Crews × Sequence	15	156,072	10,404.8	2.01	2.01	2.70
Crews × Trials	10	49,142	4,914.2	1.05	2.16	2.98
Sequences × Trials	6	89,784	14,964.0	2.9	2.42	3.47
Crews × Sequences × Trials	30	155,148	5,171.6	–	–	–
Total	71	3,281,197	–	–	–	–

REFERENCES

(1) Mackersey, I. – *Into the Silk*, HALE, 1956.

(2) Martin, J. – *Ejection from High Speed Aircraft*, J. ROY. AERO. SOC., 60, No. 550, P 659, 1956.

(3) Frost, R. H. – *Escape from High Speed Aircraft*, STANLEY AVIATION CORP., 1956.

(4) Neely, K. K. – Personal Communication, 1958.

(5) Martin, J. – *Ejection Reports*, MARTIN-BAKER AIRCRAFT CO., DENHAM, ENGLAND, 1957.

(6) Summary of CF-100 Ejections, RCAF DIRECTORATE OF FLIGHT SAFETY, 1958.

(7) Steer, M. D. et al – *Voice Communication: Effects of Stress Conditions on Speaker Intelligibility*, PURDUE RESEARCH FOUNDATION, PROJECT 20-K-1, REPORT NO. 10, 1948.

ROYAL VISIT 1959

H.R.H. The Prince Philip has graciously consented to address engineers and scientists at a luncheon at the Royal York Hotel, Toronto, at noon on Monday, June 29th. Groups participating are:

CANADIAN AERONAUTICAL INSTITUTE
CANADIAN COUNCIL OF PROFESSIONAL ENGINEERS
CANADIAN INSTITUTE OF MINING AND METALLURGY
CHEMICAL INSTITUTE OF CANADA
ENGINEERING INSTITUTE OF CANADA

Applications for tickets should be made immediately to:

Engineers and Scientists Committee
P.O. Box 62,
Postal Station Q,
Toronto 7, Ont.

The ticket allotment will be one to a person and the applicant must indicate his registration with one of the organizations participating. Tickets are non-transferable.

A cheque in the amount of $5.00, payable at par in Toronto, must accompany each individual application. Cheques should be made payable to the Engineers and Scientists Committee.

Distribution of tickets will be made on June 1st taking into consideration

(1) Order of receipt of application
(2) Fair distribution to participating organizations

THE U.S. ARMY ORDNANCE CORPS ENVANAL PROGRAM†

by H. M. Bunch*

Southwest Research Institute

THIS paper is a discussion of the US Army Ordnance Envanal System, a program designed to indicate the ability of Ordnance equipment to operate in severe ground environments through the use of numerical ratings. The program was initiated in 1951; the code name "Envanal" was a contraction of the words "environment" and "analysis".

One of the more interesting tasks of those personnel assigned to the Envanal program has been to explain the validity of the system to other engineers and scientists. "How", the Envanal researchers have been asked, "can any statistical evaluation or numeral rating system accurately predict the performance limitations of equipment in all of the infinite combinations of environment that can occur?" The answer is, of course, that the Envanal system does not attempt to make a finite prediction of item reliability; rather it attempts to deduce only general performance capabilities from specific test results.

The need of the Corps for a program such as Envanal is apparent when one considers the organization's function and role in the nation's defense. The Ordnance Corps is, among other things, charged with the responsibility of developing and making available to the Services combat and tactical support vehicles, most types of ammunition, and nearly all of the guns, rifles and mortars. World conditions require that this equipment be capable of operation at a moment's notice in almost any world environment. Too, the Corps has the responsibility of being able to tell the user which piece of equipment will give the best performance, even though any of several available types would meet the minimum requirements. And, finally, the Corps must be able to deliver equipment that is compatible with current trends and performance requirements established by the Department of Defense.

As a result of this important role, the Ordnance Corps must be continually engaged in research and development, procurement, and "selling" of materiel to the user forces. This multifarious role requires a concentrated specific performance knowledge by some personnel, while other groups are required to have broad, general information of all items.

An engineer in evaluating Ordnance trucks against an established standard or specification would be primarily concerned with knowing exactly what would happen at all points in and on a vehicle during its operation. A staff planner, though, would need to know only whether that vehicle would or would not operate in a particular environment. Thus, all the specific data collected by the engineer would be superfluous to the staff planner. Envanal was launched to fulfill the need for general, brief data reflecting equipment performance as affected by environment.

The specific objective of the Envanal program, as stated in an early official report[a], was "to develop a valid and practical method of recording data reflecting the performance of Ordnance equipment and for comparative presentation of such data so as to indicate performance limitations under various world-wide environmental conditions, thereby insuring selection of the most suitable standard and special equipment for use in any given operational area".

At the very beginning, several fundamental principles were set forth. They were:

(1) Any environmental situation represents a complexity of conditions, and the variety of combinations within any one condition may be infinite.

(2) The environmental factors selected for consideration on the Ordnance Corps Envanal Chart are of a generalized and all-inclusive nature by reason that specific environmental situations apply only to localized areas under certain seasonal or atmospheric conditions and cannot, therefore, be predicted for strategic planning purposes.

(3) In order to provide ratings of equipment performance with maximum accuracy and validity, only actual test or operational data would be utilized[a].

In the early stages, the Ordnance Envanal system, as conceived, was to be used only in the initial phases of planning a campaign and to aid in selecting that equipment *best suited* to perform in an area. In the wide variety of items that are available, one item can logically

†Paper read at the Joint I.A.S./C.A.I. Meeting in Ottawa on the 7th October, 1958.

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[a]The Ordnance Corps Envanal Chart, Aberdeen Proving Ground, August 24, 1953.

do a better job than another; however, this selection is one that is normally done only by the planning staff, and there appeared to be no place for an Envanal chart or system at any low echelon of the military services. Later, this original concept was enlarged because it was felt that the establishment of such a system would benefit the research and development agencies by providing a ready source of information for determining areas for further development.

In the several years that have elapsed since the inception of project Envanal, much progress has been made, particularly in the development and standardization of simple, easily applicable ratings and methods of data presentation. In addition, substantial progress has been made in selection of environmental criteria sufficient to cover the spectrum of environmental conditions, yet not so complicated as to cause confusion. The final outcome was a chart-type format with three general divisions: environmental parameters, tests conducted, and the performance ratings received. This, of course, is in addition to definitive information concerning the equipment, such as name of item, facilities used in testing the item, location and date of tests.

RATINGS

Currently, the ratings are equated against the specifications entitled, Army Regulation 705-15, *Operation of Material Under Extreme Conditions of Environment.* (The US Air Force, incidentally, has a similar regulation for ground equipment, HIGED, *Handbook of Instructions for Ground Equipment Designers.*) The scale, ranging numerically from 1 through 5, is as follows:

(1) Satisfactory

The item gives satisfactory performance as regards the given factor.

(2) Conditionally Satisfactory

Satisfactory performance can be acquired only with kits provided for reinforcing or modifying the equipment against the environmental factor for which it is being rated. (Can meet stress by resistance and reinforcement, or by modification – which may mean new lubricant etc, rather than a kit.)

(3) Generally Satisfactory

Some slight modification in the design or manufacture of the item is needed, or the item will not quite meet the exact performance requirements as set forth in the specifications.

(4) Generally Unsatisfactory

The items perform inconsistently, and its use under critical situations will endanger the mission and the personnel involved.

(5) Totally Unsatisfactory

The development of a new item to perform essential functions required. The item should never be used under this environmental condition, as it will probably result in a sacrifice of the personnel involved in its use.

The preceding scale, even though arbitrary, was adopted because of (a) its simplicity and (b) fairly clear-cut delineation in the various plateaus. It is realized, however, that there may be room for improvement in the rating method, and research is continuing with the ultimate goal of a scale that will (1) have the same relative differential in performance between plateaus and (2) be concise enough that the field engineer will have no trouble in affixing a performance value commensurate with the tested item's performance.

ENVIRONMENTAL CONDITIONS

During the several years the Envanal system has been in operation, many detailed environmental factors and their combinations were studied before it was decided to isolate each environmental condition as a separate testing base; otherwise, the number of combinations would have been infinite and the entire program cumbersome. After many conferences with test agency personnel, agencies responsible for program planning, and other interested parties, the following environmental conditions were decided upon because (a) of adequacy of coverage to presently encountered environmental conditions over the world, (b) general ability of the field and laboratory testing agencies to conduct tests and to isolate and record a rating for each of these specific environmental conditions, and (c) general conformance of the separate environmental conditions with those established by Army Regulations and governmental design requirement specifications.

AUTOMOTIVE

ARCTIC

Surfaces
(1) Paved
(2) Prepared gravel
(3) Hard unprepared surfaces
(4) Ice
  (a) Smooth
  (b) Rough
(5) Snow
  (a) Hard packed
  (b) Dry snow (Powder to 18″)
  (c) Dry snow (powder over 18″)
  (d) Dry snow (compact to 18″)
  (e) Dry snow (compact over 18″)
  (f) Wet snow
(6) Hilly
Temperature
Suspension Particles
(1) Snowfall
(2) Blowing snow
(3) Ice fog
(4) Sleet
Wind
Vegetation
(1) Brush
(2) Forest
Windchill

DESERT

Surfaces
(1) Paved
(2) Prepared gravel
(3) Hard unprepared surfaces
(4) Stony or rocky
(5) Gravel, loose
(6) Sandy soils
  (a) Desert pavement
  (b) Dune sand
  (c) Prepared sand slope – 10%
  (d) Prepared sand slope – 15%
  (e) Prepared sand slope – 20%
  (f) Sand plain (loose sand)
Water
Mud
Temperature
(1) Test ambient
(2) 115°F below 3,000 ft alt
(3) 125°F below 3,000 ft alt
Solar Radiation
Suspension Particles
(1) Dust (air-borne)
(2) Blowing sand
Rainfall
Altitude
Terrain
(1) Hilly
(2) Mountainous

AMMUNITION AND/OR WEAPONS

ARCTIC

Surfaces
(1) Paved
(2) Frozen muskeg
(3) Stony or rocky
(4) Gravel
(5) Silts, clays, and mixtures
(6) Ice
  (a) Smooth
  (b) Rough
(7) Dry snow
  (a) Compacted
  (b) Powdery
(8) Wet snow
(9) Water surfaces
Suspension Particles
(1) Rainfall
(2) Snowfall
(3) Sleet
(4) Moist fog
(5) Ice fog
(6) Blowing snow
Windchill
Wind
Temperature
Altitude
Humidity

DESERT

Surfaces
(1) Paved
(2) Stony or rocky
(3) Gravel
(4) Sandy soils
  (a) Desert pavement
  (b) Dune sand
(5) Silts, clays, and mixtures
(6) Water surfaces
Suspension Particles
(1) Rainfall
(2) Dust (air-borne)
(3) Blowing sand
Solar Radiation
Wind
Temperature
Altitude
Humidity

DATA PRESENTATION AND ANALYSIS

Figure 1 shows an Envanal Performance sheet on a typical piece of Ordnance equipment. In the illustration a hypothetical vehicle (Tank, 90mm Gun, M100) is evaluated. The chart shows the test vehicles were modified from the standard units because of a different engine (Engine AV-1790-4C) and also because of experimental road wheels. In all instances the test vehicles were combat loaded (97,000 lb total weight) and were instrumented with standard apparatus.

There was ample space provided on the chart for indicating the source (or sources) of the ratings. In the case of the illustration, it is seen that the vehicle was tested at Yuma (Ordnance Desert Test Activity) in 1956 and 1957 and at Detroit Arsenal in 1958. In the illustration, too, nine tests pertinent to Envanal evaluation were conducted over the three year period. (Note: There has been a grouping of any vehicle test authorized by the Ordnance Proof Manual into one of thirteen divisions. Tests of other Ordnance items are designated to one of 27 or 31 alternatives, depending upon the item.) As is typical of all Envanal charts, there are, in the "note" section, explanations of any rating other than a "1" (Satisfactory).

Presently, there is incorporated into the system another step of consolidation whereby ratings on the individual sheets similar to Figure 1 are abstracted to a "Summary Data Sheet". The advantage of this consolidation is apparent when one considers that all of the U.S. Army Ordnance automotive vehicles are listed on only three pages of summary sheets. There is provided, then, a facility ideal for fast review and as a decision aid.

One of the methods currently used for aiding in decisions is statistical analysis of the charts. Examples of the more simple techniques are standard deviation studies, and mean and median analysis (both weighted and unweighted). More sophisticated analysis would be typified by probability evaluation.

Typical of the studies that have been made, or that will be conducted, using the Envanal charts as a basis for calculation, are:

(a) An evaluation of the standard deviations in ratings in each of the environments. This can give indications of discrepancies in test plans, severity of environment, adequacy of the base specification etc.

(b) A long-term study of the rating averages, medians, and other statistical indices to evaluate possible changes in equipment capabilities and the effect of specification changes.

(c) Predictions of an item's chances of completing a specified mission through proper use of probability theory and weighting of the necessary variables. To date, though, this area of study has not been undertaken.

Unfortunately, there has been a limiting factor to the use of statistics in Envanal. This is apparent when one considers the high cost of many Ordnance items. Testing the number of tanks, for example, to a point where statistical certainty could be achieved would be astronomical in cost. As a result, only one, or perhaps two, prototype vehicles are tested on many occasions. This adversity has been partially overcome, however, by familiarity of the Envanal evaluator with the item's component capabilities. The knowledge helps to determine the reliability of the items; and while it might appear haphazard, the accuracy of the method has been accepted by many statisticians, particularly when a large number of decisions must be made. The "plus" and "minus" decisions tend to cancel each other with the result of a small margin of error over the entire program.

APPLICATIONS

Through the use of the charts themselves and also of the statistics that can be obtained therefrom, many benefits have been derived. Interestingly enough, most of them were unanticipated in the early phases of the program development.

Primarily, the system is a method of affixing an appropriate numerical rating to indicate the ability of a piece of equipment to meet an environmental specification. This, in turn, indicates the item's capacity to operate in the environment. The charts, when current, should then provide a ready reference as to which piece of equipment will perform best in a given area of the world. In addition, the charts indicate potential trouble points in operating equipment in a specified environmental condition, thus giving those involved at staff and higher field levels time to take steps to minimize the effect arising from those problems.

Program planners at various levels have benefited from the Envanal charts. The system has served as a ready reference for indicating under what conditions equipment has not been sufficiently tested. This has resulted, in some instances, in helping to establish priority preference.

Personnel at both the design and test levels have benefited from the Envanal system. The design engineers have been able to utilize the rapid reference source of how other equipment performed in the environments. The test engineers, likewise, have been able to utilize the Envanal charts when comparing a current program with past tests.

While the Envanal system has progressed rapidly and is currently well advanced in its development, the importance of the potential uses of the system indicate continued research. At this point, it appears that future emphasis will be upon more sophisticated mathematical research into the system.

One thing is certain: the US Army Ordnance Corps has sponsored the development of a rather unusual evaluation program, which over the years has produced many satisfactory results. And, even though the program is currently involved in evaluating only items indigenous to a ground environment, there is no reason to believe that the system cannot be applied to other areas of equipment evaluation.

Because of the security classification of the program, only very general information pertaining to Envanal is contained in this paper. Anyone who can establish the customary "need-to-know" qualification may obtain more information regarding the Envanal charts by contacting the contract administrator: The Commanding General, Development and Proof Services, Aberdeen Proving Ground, Maryland, Attention, ORDBG-DP-DF.

RECORD OF PERFORMANCE DATA SHEET

EQUIPMENT TESTED:

TANK, 90MM GUN, M100 (STANDARD)
W/ ENGINE MODEL AV-1790-4C
W/ EXPERIMENTAL ROAD WHEELS (1957)

FACILITIES:

COMBAT LOADED, TOTAL 97,900 LBS.
STANDARD TEST INSTRUMENTATION

REPORT NO., LOCATION AND DATE OF TEST
YUMA TEST STATION, SUMMER, 1956,
REPORT TBS-1401/900/1
YUMA TEST STATION, SUMMER, 1957,
REPORT TBS-1401/900/2
DETROIT ARSENAL, 1956,
REPORT CL 895

EXTENT OF TEST

TEST NO.	TYPE	NO. OF ITEMS	EXTENT	AMB. TEMP MIN	AMB. TEMP MAX
1	FULL LOAD/THROTTLE	2	YTS 56-57	103	112
2	ROAD LOAD COOLING	2	YTS 56-57		107
3	VAPOR LOCK	1	YTS 57 DA 58		125
4	FIRE DIRECTION	1	YTS 56	103	112
5	MOBILITY	2	YTS 56-57	103	112
6	STORAGE (EXPOSED)	1	DA 58		125
7	OCTANE RATING	1	YTS 57	106	109
8	ENDURANCE	2	YTS 57	103	110
9	CREW COMFORT	2	ALL	103	125

ENVIRONMENTAL FACTORS

TEST NO.	A PAVED SURFACES	B PREPARED GRAVEL SURF.	C HARD UNPREP. SURFACES	D STONY OR ROCKY GROUND	E GRAVEL, LOOSE	F SANDY SOILS (DESERT PAV.)	G DUNE SAND	H PREP., SAND SLOPE - 10%	I PREP., SAND SLOPE - 15%	J PREP., SAND SLOPE - 30%	K LOOSE SAND (BEACH)	L WATER	M TEMPERATURE	N SOLAR RADIATION	O DUST, AIR-BORNE	P BLOWING SAND	Q RAINFALL	R ALTITUDE	S HILLY OR MOUNTAINOUS	T	U	V	W	X
1	1												3											
2	1	1			1	1	4				1													
3													1				1							
4	1	1											1		4				3					
5	1	1	1	1	1	1	1	1	1	1	1						1							
6														1			3							
7													1				1							
8	1	1	1	1	1	1							1											
9														3	3	3								

NOTES:

1-M VEHICLES EXCEEDED SPECIFICATION IN FOLLOWING AREAS WHEN TEMPERATURE EXTRAPOLATED TO 125 DEGREES F; CRANKCASE OIL, 255 DEGREES F (SPECIFICATION 250 DEGREES). RESULTS CONFIRMED AT CLIMATIC LABORATORY TESTS IN 1958; HOWEVER, DEFICIENCY NOT CONSIDERED EXTREMELY SERIOUS.

2-G CONTINUED OPERATION IN DUNE SAND EXCESS OF 25 MINUTES CAUSES SEVERE OVERHEATING OF TRANSMISSION LUBRICANT (335 DEGREES F).

3-M, R TEST SATISFACTORY WITH 8 LB. RVP FUEL TO 6000 FT. ABOVE SEA LEVEL.

4-O CONTINUED OPERATION IN DUST CAUSES SEVERE IMPAIRMENT OF TURRET MOBILITY.

4-S ELEVATION LIMITS 300 MILS, DEPRESS 150 MILS.

6-Q TURRET RACE BEGAN TO RUST AFTER 3 WEEKS EXPOSURE IN HIGH HUMIDITY. CONTINUED EXPOSURE COULD AFFECT FIRE DIRECTION.

8-A SINUSOIDAL VIBRATION ON HARD, PAVED SURFACE CAUSED SEVERAL WELD FAILURES.

9-N TEMPERATURE ROSE TO 138 DEGREES F WITH AN AMBIENT OF 125 DEGREES F.

9-O, P VISIBILITY SEVERELY IMPAIRED WHEN OPERATING IN THESE ENVIRONMENTS.

9

Figure 1
Illustration of typical vehicle Envanal chart

C.A.I. LOG

SECRETARY'S LETTER

My tour of the western Branches, which usually takes place in January, was delayed this year but I managed to make a hurried trip in the middle of April. I accompanied Dr. D. C. MacPhail, our Vice-President, as far as Edmonton and then he had to return to Ottawa, while I went on to Cold Lake and Vancouver on my own.

WINNIPEG

Our first stop was at Winnipeg where we spent the night of the 13th April. We paid a brief visit to Bristol's Winnipeg Division and later had dinner with some of the Branch Executive Committee. Mr. E. V. Bunnell, their Chairman, had the makings of a shocking cold but he bore up nobly. We had a very enjoyable and useful evening, discussing all manner of Institute and Branch affairs. We were glad of the opportunity to review some of the problems confronting Mr. W. E. Robinson, a member of the Council and Chairman of the Planning Committee; as can be imagined, in the present circumstances, the crystal ball is a trifle hazy.

CALGARY

Next morning we went on to Calgary, arriving about noon. This was our first visit to Calgary since the formation of a Branch and we were particularly sorry that we had not timed our visit to coincide with a Branch meeting. The Branch has done well and has built up its membership to rather more than 50 in less than a year.

We were met at the airport by Mr. W. A. B. Saunders, the Branch Chairman, and most of his Executive Committee, and had lunch with them there. Afterwards we went to the Provincial Institute of Technology and Art and were shown around by Mr. J. D. Zmurchyk. Every time I go to Calgary they have some new building to brag about; I must say the P.I.T.A. is a most impressive place and a very great asset to Canadian aviation (and to a lot of other Canadian activities as well). Before we left we sat down in a vacant office and had a general discussion of current problems.

EDMONTON

We went up to Edmonton the same evening and had dinner with the Branch Executive Committee. Mr. J. G. Portlock met us at the airport and kindly took us to our hotel, but he was unable to join us later. Even for this short time it was good to see him again; he was the "Interim Secretary" and, later, the first Chairman of the Edmonton Branch.

Mr. C. C. Young, the present Chairman, and his energetic Executive Committee have staged a very good programme this year. Though local conditions have been rather difficult, I think they are over the worst and the future of the Branch seems quite bright. Edmonton is always full of ideas about the Institute and on every visit I can count on a lively and entertaining discussion of Headquarters' shortcomings; we were not disappointed and enjoyed our dinner with them immensely.

The next morning Dr. MacPhail and I visited Northwest Industries for a while before his plane took him back to Ottawa. Then I had quite a long discussion with Mr. Young about the plans for the Mid-season Meeting 1960, which will be held in Edmonton next February. There is nothing very much I can say about this yet, except that we are hoping to arrange things so that the Students from Calgary will be able to attend in force.

COLD LAKE

I visited Cold Lake on the 15th April and was very glad to find that they had been able to rearrange the date of their April meeting to fit in with my visit. In spite of its rather shifting population and the fact that my visit last year was frustrated by bad weather, I met many old friends there – some had even shifted in from other Branches. In the face of transfers and the many counter-attractions laid on by the Station, this small group has managed to keep up its membership and, evidently, its enthusiasm. It has certainly set an example that other RCAF Stations might well copy. F/L L. S. Lumsdaine, their Chairman, and his Executive Committee are to be congratulated.

Before I left the following morning, Mr. E. K. Prentice took me for a drive around the hinterland, to the towns of Grande Centre and Cold Lake. This was the first time I had seen northern Alberta free from snow – actually it was tinder dry and they needed rain badly – and I was surprised to find how many people live in that remote part of the country.

VANCOUVER

And so back to civilization and over the mountains to Vancouver, where I had another meeting with the Branch Executive Committee, in fact with the best part of their incoming and outgoing Executive Committees; they had just held their Annual General Meeting and I found it difficult to remember who was in office and who had just retired. Mr. J. R. S. Hutton, their new Chairman, must forgive me for constantly addressing my remarks to Mr. R. J. McWilliams, the Past Chairman, but talking to Mr. McWilliams about Vancouver affairs has become something of a habit during the last few years.

This again was a very useful meeting and I wished that the Vice-President had still been with me; for Vancouver, as our oldest Branch – not counting the Toronto/Montreal/Ottawa triangle – always has some interesting things to say about many aspects of the Institute's work. I kept them up much too late talking about everything.

NEXT TIME

The Branches were very pleased to see Dr. MacPhail and I am sure that I speak for Winnipeg, Calgary and Edmonton in thanking him for his visits. He made these visits in his capacity of Vice-President, because the President, whom I had approached about it, simply could not go at such short notice and at this time of year.

In future we must plan this thing better and I propose to discuss it with the Programmes Committee. My annual flittings in and out cannot satisfy the Branches; they want to see the President (or his Vice) and at full-dress Branch meetings. The tour should be planned some time in advance, to suit the President's convenience and the Branch programmes. I am sure that the President would enjoy the trip as much as the Branches would enjoy seeing him.

And we must not forget that Halifax-Dartmouth must be fitted into this Presidential Progress too.

HEADQUARTERS OPERATIONS

Because, as I said above, the crystal ball is not very helpful just now, the Council has decided that we must cut down Headquarters' staff, as a precaution against running into financial difficulties. With a total staff of six, the loss of even one person will make a big difference to the services we can render. We shall try to rearrange things to use our remaining strength to the best advantage but I would ask our members to bear with some falling off in the speed with which we can answer letters, acknowledge the payments of their dues and so forth. This is the time of year when we are winding up the season's activities in preparation for the Annual General Meeting and the load is fairly heavy upon us.

ANNUAL GENERAL MEETING

There are one or two features of this year's Annual General Meeting on which I should like to comment at more length than was possible on the Meeting Notice.

Firstly, it will be noted that the arrangement shown on page 129 of the April issue has been changed. The unveiling of the Monument will take place at the beginning of the Meeting, on the Monday, and not on the Wednesday, and this has resulted in a general reshuffle. The Annual Dinner will now be held on the Tuesday, the 16th June. The official programme will close at midday on the Wednesday to enable people to get back to Sydney in time for the evening flights.

Secondly, there is the problem of getting to and from Keltic Lodge, which is located quite a long way from Sydney, the nearest airport. Normally there is a bus – so far as I know, only one service a day – and, I suppose, taxis can be obtained at a price. A committee of our members in Halifax-Dartmouth is working on the problem and we think that we can arrange special transportation. But our first problem is to know when people are liable to arrive at Sydney and, in fact, we must exercise some control of these arrivals so that we can apply the available ground transportation services to the best advantage. For this reason we sent out special cards with the Notice. If anyone going to the Meeting by air has not sent in his card by the closing date (20th May) I should still like to hear from him; we may still be able to advise him and perhaps fit him into an empty seat if he is in difficulties.

Finally, all the rooms, in the Lodge and in the cottages, are double rooms and the total accommodation is limited to about 180. We would therefore ask people to be prepared to share; we have to use all the space there is and "single occupancy" is a luxury which may mitigate against the success of the Meeting. I am sorry about this, but I didn't build Keltic Lodge and the whole affair will be rather gay and informal anyway I hope. Let us not be too fussy.

In support of my last point, I would quote from a letter I have received from Mr. McCurdy in which he confirms that he will be there with us, and adds,

> "I hope you all enjoy that part of Canada – and have good weather. Tell the boys to take their golf sticks as there is an excellent golf course there."



ANNUAL GENERAL MEETING

Programme

June 15th Morning 10.00 a.m.

Transportation will leave Keltic Lodge for Baddeck. A buffet lunch has been arranged for in Baddeck, following which there will be the unveiling of the Monument at 2.30 p.m. in the grounds of the Alexander Graham Bell Museum. Transportation will leave Baddeck for Keltic Lodge at 4.00 p.m.

June 15th Evening 8.30 p.m.

BUSINESS MEETING

President
Dr. G. N. Patterson
Director, Institute of Aerophysics
Annual Reports of the Council and of the various Committees

June 16th Morning 9.00 a.m.

TEST PILOTS SECTION

Chairman
E. V. Bunnell
Sales and Contracts Manager, Aircraft
Bristol Aero-Industries Ltd. (Winnipeg Division)
Annual General Meeting – Business Session

PROPULSION SECTION

Chairman
J. J. Eden
Powerplant Engineer
Trans-Canada Air Lines
Annual General Meeting – Business Session

ASTRONAUTICS SECTION

Chairman
Dr. H. S. Ribner
Associate Professor of Aeronautical Engineering
Institute of Aerophysics, University of Toronto
Annual General Meeting – Business Session

June 16th Morning 10.30 a.m.

HYDRODYNAMICS

Chairman
M. S. Kuhring
Head, Engine Laboratory
National Research Council

The Influence of Cavitation on Hydrofoil Craft Design
M. C. Eames
Defence Scientific Service Officer
Naval Research Establishment

Ditching Tests on a Model of a Large Reconnaissance Aircraft
E. S. Turner
Head, Hydrodynamics Section
National Research Council

June 16th Afternoon 2.30 p.m.

HONOURS AND AWARDS

Chairman
Dr. G. N. Patterson
President, Canadian Aeronautical Institute

Honorary Fellows
McCurdy Award
F. W. (Casey) Baldwin Award

and

The W. Rupert Turnbull Lecture
Air Survey – The Key to National Resources
D. N. Kendall
President, Photographic Survey Corporation

June 16th Evening 7.00 p.m.

DINNER

Chairman
Dr. G. N. Patterson
President, Canadian Aeronautical Institute

Address
The Development of Canadian Aeronautical Engineering
Professor T. R. Loudon
The De Havilland Aircraft of Canada Limited

June 17th Morning 9.00 a.m.

FLYING — PAST, PRESENT AND FUTURE

Chairman
S/L O. B. Philp
Directorate of Flight Safety, RCAF

The Record of the Past
J. R. K. Main
Director, Civil Aviation Branch
Department of Transport

Canadian Aviation – The Fiftieth Year
F/L J. H. Waldie
Central Experimental and Proving Establishment, RCAF

Some Thoughts on the Next Fifty Years of Flight
W/C P. A. Hartman
Directorate of Maritime, Tactical,
Transport Training Requirements, RCAF

BRANCHES

NEWS

Winnipeg

Reported by G. Milner

March Meeting

The March meeting of the Winnipeg Branch was held on the 29th March at the Winnipeg Flying Club. The dinner was attended by 57 members and guests, the lecture portion by over 100. The speaker for the evening, Mr. F. T. Moore, Project Engineer, DC-8, of Trans-Canada Air Lines, was introduced by Mr. B. W. Torell, Vice-Chairman of the Branch. Mr. Moore opened his address by comparing his first trip to Winnipeg in a Lockheed 1408, which took 8½ hrs to fly from Toronto to Winnipeg, with the DC-8, which will make this same trip in 2 hrs 35 mins. The 1408 carried 14 passengers and a total cargo load of 3,100 lb. The DC-8 will carry 162 passengers and more than 13 times the payload of the 1408. The DC-8 at takeoff will consume the total fuel capacity of a 1408 in somewhat less than 5 mins.

Although only 13 years have passed since this condition existed, the transportation industry has moved at such a rate that comparisons with equipment of this age are unfair. Mr. Moore then went on to compare the DC-8 with a Lockheed Super-Constellation now in trans-continental operation by TCA.

The DC-8 is designed to fly at 575 miles per hour at an altitude of 35,000 to 40,000 ft. Its gross takeoff load is 310,000 lb and the approximate cost is $6,000,000 each. The DC-8 has 16 ft more wing span, is 37 ft longer and stands 16 ft higher than the Super-Constellation. The vertical stabilizer is the height of a 4 storey building. A machine of this size introduces major storage and hangar problems, which together with the high cost of operation and high initial cost means that it must operate at a high load factor to realize any returns on the investment.

Mr. Moore dealt briefly with the development of the DC aircraft from the time of the DC-1 to the present DC-8, stressing the point that the Douglas aircraft have been a success in each model. He also paid high praise to the engineers of Farnborough who reconstructed the Comet crash from the Mediterranean. The results of this investigation, which were made available to all aircraft design companies, have resulted in a completely new concept in pressurized aircraft construction. Mr. Moore then went on to describe the aircraft in detail, section by section.

In summarizing the DC-8, TCA believes it has the ability to do the work of 3½ Super-Constellations, 19 DC-3's, 32 average size buses, 236 automobiles, 880 stagecoaches or 1 ocean liner. Its introduction to the air routes of this country will present to the general public the latest in luxury, speed and safety.

The meeting was completed with the showing of two Douglas film reports entitled "DC-8 Report No. 1" and "No. 2".

The speaker was thanked by Mr. D. A. Newey.

Halifax-Dartmouth

Reported by Lt. J. A. Turner

March Meeting

The monthly meeting was held in the cinema of the CPO's Mess, HMCS Shearwater, on Wednesday, 18th March, 1959. Mr. R. Wallworth, Vice-Chairman, presided over the meeting.

A report was presented by the Fiftieth Anniversary Committee which showed conclusively the outstanding success of the commemorative banquet held on the 23rd February, 1959. The Chairman then introduced the nominees for the new Executive to those in attendance.

The speaker, Mr. J. G. McArthur, of the Naval Research Establishment, was introduced by Mr. M. C. Eames. In his introduction, Mr. Eames noted that it was most appropriate that the speaker should be giving a talk on "Electronic Computers" in view of his contributions in this field at the Naval Research Establishment.

The speaker outlined the development of the computing devices from the ancient abacus, which is still used in some Oriental countries, to the complex electronic computer systems in use today. He explained briefly the basic principles of the various types of systems and then went on to explain how they could be used to advantage in industry and research. In order to give the audience some appreciation of the complexity of the computing systems, slides were shown periodically throughout the lecture.

It was noted that the type of computer most suitable for a specific function would depend mainly on the type of information required. The contribution which the electronic computer has made in the field of science in recent years has been invaluable. Problems which took virtually years to solve, by conventional means, can now be solved in a matter of minutes.

The interest in this field by the 16 members and guests present was clearly shown by the lively discussion which ensued.

The speaker was thanked by Mr. R. Wallworth.

Vancouver

Reported by G. W. T. Roper

March Meeting

As in previous years, a joint meeting was held with the Society of Automotive Engineers, Vancouver Branch, and the Canadian Aeronautical Institute, Vancouver Branch, on the 26th March at the Georgia Hotel.

After approximately 80 members and guests enjoyed the usual dinner festivities, the meeting was called to order by our Chairman, Mr. R. J. McWilliams, who was obliged to substitute for the SAE Chairman on last minute notice. Following some very timely remarks, Mr. McWilliams introduced the speaker of the evening, Mr. M. L. Pennell, Chief Engineer, Transport Division, Boeing Aircraft Company of Seattle. The chosen subject was the 707 and its effect on future air transport. The entire paper dealt with today's turboprop – turbojet aircraft, the difference in types of engines and relative costs, and general operation of same. Mr. Pennell indicated his belief that the introduction of the Rolls-Royce Conway bypass engine and the American counterpart – the fan type engine – could possibly be developed to reduce fuel consumption to the point where they would be as economical to operate as the turboprop. Mr. Pennell further outlined his belief that the subsonic commercial aircraft, which is currently being introduced, would most likely fill airline requirements for the next 10 years, at which time supersonic aircraft, capable of attaining speeds of 1,800 to 2,000 miles per hour, may be available for commercial use. Mr. Pennell concluded his paper with his views on the future in air cargo. He felt that, with the larger subsonic aircraft becoming available, air cargo handling throughout the world could be achieved at reduced costs, making it possible for air cargo hand-

ling to equal or near equal passenger revenue. In summarizing his paper, Mr. Pennell indicated that a lot has been learned of the jet age but many problems are yet unanswered and that answers to these problems would be necessary before a satisfactory supersonic aircraft could be developed for commercial use.

A very lively question and answer period followed and the meeting concluded after the Superintendent of Maintenance for the B.C. Electric Company thanked the speaker on behalf of the membership for a most enjoyable and informative paper.

Ottawa

Reported by R. L. Wardlaw

April Meeting

Mr. H. H. Kelland, Branch Chairman, presided over the meeting held in the RCAF Beaver Barracks. He introduced the guest speaker, Dr. H. F. Dunholter, Assistant Chief Engineer (Development) of Convair Astronautics.

Dr. Dunholter, speaking on "The Space Race", outlined the proposed programme for space studies put forward by the National Aeronautics and Space Administration. A long range programme is envisaged incorporating the development of a series of four flight vehicles, each capable of a variety of missions. Each successive vehicle will have considerably greater payload than its predecessor, the first being capable of carrying 2 to 3 tons into a satellite orbit, and the third capable of carrying 15 tons into orbit or 2½ tons on a lunar probe, while the final vehicle would be capable of a manned return lunar flight. The development of five new rocket engines is proposed, ranging in thrust from 6,000 to 1,500,000 lb. Several different missions are being considered. For studying man's manual and mental capability when in a weightless or zero g condition, a two day manned orbital flight is planned. A high drag capsule protected by an ablating material and using retro-rockets for reentry would be used. For a more accurate reentry and landing, a gliding vehicle is also proposed. Another mission is the establishment of a space station and one purpose of this would be the training of men for the lunar flight mission. Dr. Dunholter also stressed the importance of space research in carrying out scientific experiments into such fields as astronomy and communication.

Dr. Dunholter followed his talk with the showing of an excellent film of the firing of an Atlas missile at the Atlantic Missile Range. The film also showed the elaborate preparation required for the success of such a firing in providing a maximum of scientific and technical information.

After a question period, the speaker was thanked by Mr. G. D. Watson. There were 48 members and 7 guests at the meeting.

Montreal

April Meeting

The meeting was arranged by members of the Astronautics Section and is reported on under Sections.

SECTIONS

NEWS

Astronautics

Reported by A. B. Oxley

Montreal April Meeting

The meeting was held on the premises of Canadair Limited on the 7th April, 1959.

Dr. H. F. Dunholter, Assistant Chief Engineer (Development) of Convair Astronautics, San Diego, was the guest speaker of the evening and his talk, entitled "The Space Race", was most enlightening, constructive and well received by his audience of about 125 people.

Between 95 and 100 members and guests attended the cocktail get-together and dinner, which was served in one of the private dining rooms at Canadair's No. 1 Plant. The head table was presided over by the Section Vice-Chairman, Mr. D. Bogdanoff, who welcomed the large turnout and commented upon the fast and enthusiastic growth of the Astronautics Section of the Institute, membership having nearly reached the 100 mark already.

Announcement was also made concerning the future plans of the Astronautics Section's participation in the University of Toronto's Institute of Aerophysics (UTIA) 10th annual symposium. The Section is conducting 2 half-day sessions and a 3-hour luncheon and panel discussion on "The Future of Canada in the Space Age", which will be discussed with some outstanding authorities and will take place at the Institute of Aerophysics in October, 1959.

After the dinner, the assembly reconvened in the Canadair theatre where Dr. Dunholter was introduced by Mr. Bogdanoff who outlined the career of this well-known scientist and engineer.

Dr. Dunholter commenced his talk by reviewing some of the highlights of astronautic progress since the Russian Sputnik was so successfully launched about 1½ years ago – along with two or three USA Senators! – at which time the United States had planned three or four shots of the Vanguard missile, the individual stages having been tested by this time. He stated that at a recent lecture at the California Institute of Technology, Dr. Silverstein, who is Director of the Space Division of the National Aeronautics and Space Administration, declared that it was his belief that all present vehicles, such as Vanguard, Jupiter and Juno III, are obsolete as far as a constructive space program is concerned and this includes the Thor Able program.

Dr. Dunholter then outlined a new basic concept involving four "Universal Vehicles" and a development program spread over the next 5 or 6 years.

The first Universal will be the Atlas Vega, which will use the regular Atlas plus an upper stage capable of putting up 2 to 3 tons gross weight with a payload of about 1,000 lb.

The second Universal, to be known as the Atlas Centaur, will comprise the Atlas Vega with a second stage oxy-hydrogen propulsion capable of boosting the payload to about 2,000 lb.

The third Universal, to be known as the Atlas Saturn, will have a new third stage booster to be built by Huntsville. The Saturn will be a four stage rocket and will weigh 750,000 lb, having a thrust of 1,500,000 lb and carry a payload of 30,000 lb. Its second and third stages will use existing high energy motors in cluster.

The fourth Universal, to be known as Atlas Nova, will have a 6,000,000 lb thrust with four engines each of 1,500,000 lb thrust for the first stage – a program to extend up to about four

years. It will be a five stage rocket standing 300 ft high and should be capable of putting a 75 ton satellite in orbit. It should enable the delivery of a man to the moon with a soft landing and be able to return with successful reentry. The second stage only will be about the same size as the present Atlas missile.

In connection with this ambitious program, there are five new propulsion powerplants to be developed. Two of them will be of the storable liquid type having about 6,000 lb thrust – one using hydrogen-oxygen propulsion of some 30,000 lb thrust, one of exotic fuel having 80,000 lb thrust, and one using gasoline-kerosene-oxygen mixture having 1,500,000 lb thrust.

Dr. Dunholter also outlined the immense amount of atmospheric and outer space research which remains to be done, since our knowledge in many areas of investigation has only scratched the surface. For instance, at Fort Churchill in northern Canada where many successful firings have taken place there are indications of a ten to one change in density of the upper atmosphere between day and night, which does not seem to have shown up at Cape Canaveral. Also, many more measurements must be made regarding the intensity and movement of the Van Allen radiation belt and the magnetic fields involved. This research has resulted in many missions and experiments being planned for a busy future.

The NASA plan to fly a passive reflective balloon 800 to 1,000 miles high, and by means of a 2,000 megacycle radio beam attempt to establish a reflective communication channel. However, to maintain a good communication channel for continuous use about twenty such reflective satellites may be necessary.

A very attractive project would be to establish a 24 hr satellite in orbit around the earth (it would always be in the same position relative to the earth) at the optimum communication distance of 22,000 miles in altitude, but this would require a terrific thrust to get such payload into orbit, apart from the difficulties of environmental testing in near vacuum of a proposed 100 ft diameter plastic metalized sphere. Inflation of the balloon when in position is also a problem, but it is believed possible to use the air entrapped when it was packed at atmospheric pressure and maintain it by sublimation of ice self contained.

To round out his interesting lecture, Dr. Dunholter then screened what was felt to be one of the most fascinating films ever produced on the 24 hour countdown procedures of a large missile, which was by courtesy of the Convair Division of General Dynamics Corp. This film, in full technicolor, truly conveyed the myriad of responsibilities concerning testing, operation and safety of range personnel during this tense period of checking and launching. It also left in the mind's eye a very healthy respect for the enormous quantity of complex ground equipment involved and the personnel who were responsible for its design and manufacture.

Following the film showing, the speaker spent some time in an active discussion period which involved many aspects of the subject. In answer to a question on the future of liquid versus solid propellants, he expressed the opinion that solid propellants are gradually overcoming some of their earlier disadvantages, such as storage deterioration, cracking and uneven burning, and still retain the many advantages of convenience and lack of control complexities associated with liquid propellants. Liquid propellants, on the other hand, permit many possibilities of control during flight and probably will continue to be used for space missiles.

Regarding the use of transistors in missile circuitry in the presence of radiation, Dr. Dunholter felt that even though the actual intensity was of comparatively low order in the radiation belts surrounding our earth, some particle energies were high – hence more investigation is necessary to determine whether transistor operation is reliable for these applications.

W/C C. R. Thompson, Chairman of the Montreal Branch, ably conveyed to the speaker the sincere thanks of the audience for the time and effort involved in coming to Montreal to deliver such an interesting and informative lecture.

APPOINTMENT NOTICES

The facilities of the Journal are offered free of charge to individual members of the Institute seeking new positions and to Sustaining Member companies wishing to give notice of positions vacant. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.

The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.

Box 107 **Designer:** Age 35, ex-Avro Special Projects and De Havilland, U.K., seeks position to satisfy wide and varied experience including installation of services and systems, static and test flight instrumentation; test rigs, models, mechanisms and electrical installations. Liaison duties and Service experience of supervision of repair, overhaul, maintenance and inspection of service aircraft and engines.

Box 108 **Flight Test Engineer:** Aeronautical Engineering graduate, Provincial Institute of Technology and Art, Calgary. Experience gained initially in commercial airline maintenance engineering, followed by a 7 year period covering gas turbine assembly and all aspects of gas turbine flight testing, including flight data analysis. Age 37. Interested in special projects connected with future airline planning.

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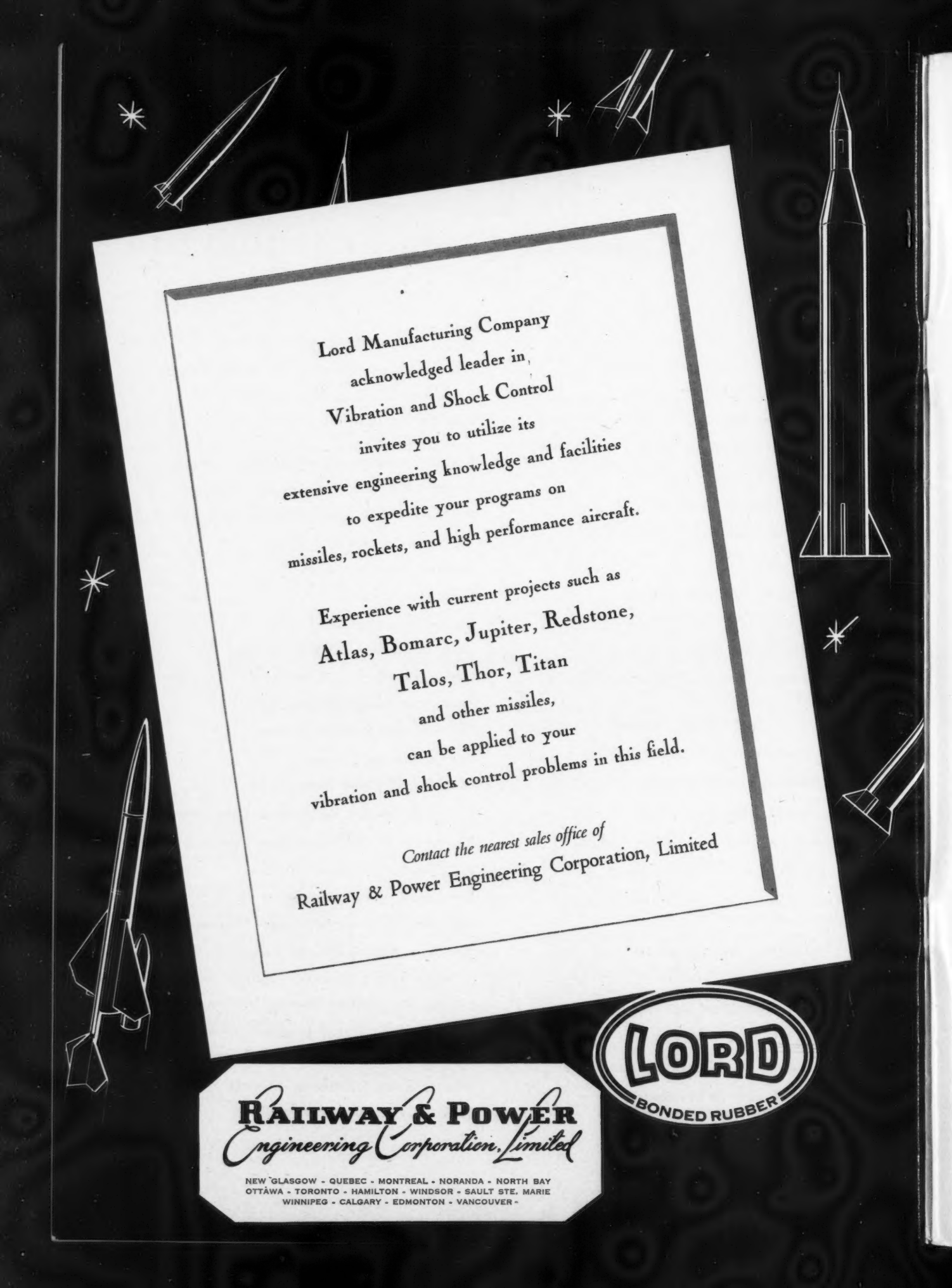
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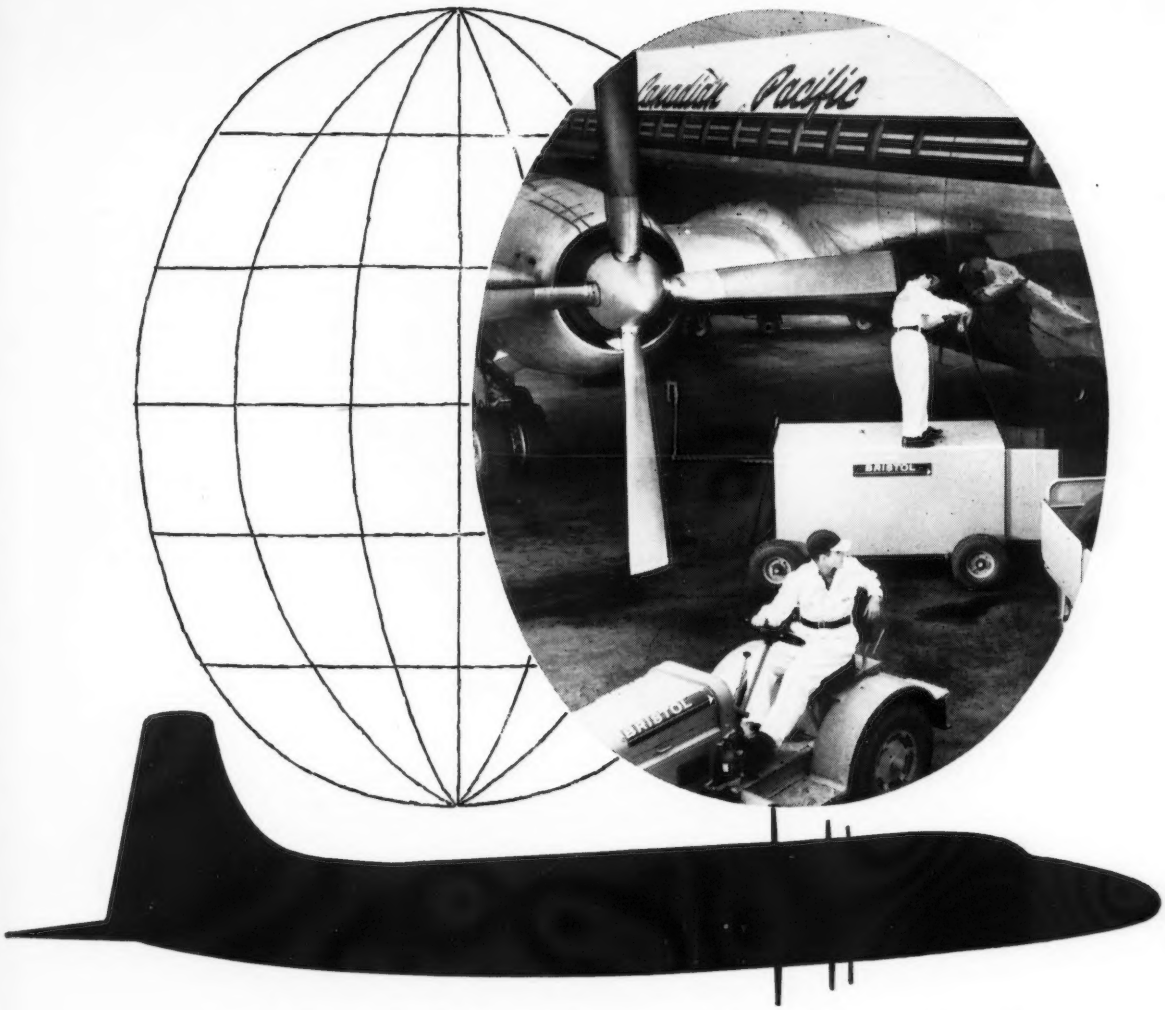
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